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THE AMERICAN PHILOSOPHICAL SOCIETY

For the Fifth International Congress of Anthropological and Ethnological Sciences, Philadelphia, September 4, 1956

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(*Read by Dr. Clyde Kluckhohn*)

HISTORY

THE American Philosophical Society was founded at Philadelphia 213 years ago, in 1743, through the efforts and energy primarily of Benjamin Franklin. The word "philosophy" was used in its etymological sense of love of wisdom or knowledge, and of course was the eighteenth-century *de facto* equivalent of our word "science."

The Society began with seven members at Philadelphia, five in New York and New Jersey, and prospects of others at a distance. Several meetings were held, but after a year or two activity languished, and no minutes have been preserved until twenty-five years after the founding, beginning in 1768.

In that year a rival organization stimulated the Philosophical Society into renewed activity. This rival, local and social in character and limited to twelve members when founded about 1758, later enlarged its membership, and in 1768 changed its name to "The American Society, held at Philadelphia, for promoting useful Knowledge." They elected Franklin as President, though he was then in Europe and was the founder of the older society.

The membership of the younger Society was mostly drawn from the more democratic or "Popular" political party of Pennsylvania, while in the Philosophical Society the somewhat aristocratic tendencies of the Proprietary party prevailed. During 1768, both societies were active and proselyted, constituting one of the rare cases of political partisanship actually stimulating scientific interests. Fortunately, however, the rivalry did not develop into conflict, possibly because of the considerable number of 26 joint memberships. By the end of 1768, articles of merger on terms of equality were adopted, and on January 2, 1769, Franklin was elected President. The older American Philosophical Society contributed 128 members, including 8 going back to the original founding in 1743; the American Society, 149 members. The main title in the designation of the new united body was taken from the older society, the subtitle from the younger one.

A transit of Venus across the disk of the sun later in the same year helped launch the Society into active scientific preoccupation. A grant of £100 was made by the Province of Pennsylvania in aid of the observations. This same astronomical activity also resulted in the issue of the first number of the Society's *Transactions*.

Incorporation of the Society by the Commonwealth of Pennsylvania took place in 1780, during the Revolutionary War; and soon after a governing Council was established.

Except for an interruption of three years when Philadelphia was occupied by British troops, fortnightly meetings were held until 1911, and then monthly ones until 1936. In 1902 an Annual General Meeting of three days was instituted and held in spring, and in 1936 a second General Meeting, in autumn, was added. This change transformed the membership attending meetings from a local to a national scope.

PUBLICATIONS

The Society's *Transactions*, the oldest scientific periodical in America, ran to six volumes from 1771 to 1809. In 1818 a new series of the *Transactions* was started in larger format. This series is now devoted to monographs, and is issued at the rate of a volume a year. A second series, the *Proceedings*, dates from 1838, includes shorter papers, whether read at the Society's meetings or not, and also aggregates an annual volume, in six numbers. In 1935 a third series was founded, the *Memoirs*, which appear irregularly in book form. In 1937 an annual *Year Book* was begun in order to free the *Proceedings* of minutes, business reports, and obituaries.

The last subject classification of the Society's complete publications was compiled in 1940. It shows up to then a total of 215 papers in the *Pro-*

ceedings and 25 monographs in the *Transactions* and *Memoirs* on topics included within the general range of what is customarily subsumed under the term anthropology in this country. By the Society's classification at that time, of these 240 publications 42 fell into the narrower field of anthropology in the European sense; 71 were in archaeology; another 71 in ethnology; and 56 in linguistics of ethnic relevance. This is a rather even distribution by fields, and the proportions appear to have been approximately maintained in the fifteen subsequent years.

BUILDING

The Society's building in which you are seated, Philosophical Hall, has had a varied history. The plot of ground on which it stands was granted by the State in 1785. The money to erect the structure came by gifts, the largest being from Franklin, who also loaned the Society the amount necessary to complete the hall. It is the oldest building, after Independence Hall, now standing on Independence Square. Meetings have been held there since 1789, except during the 1793 and 1798 yellow fever epidemics. For 143 years the basement and first floor were rented to tenants, mostly institutions, but later including agents and brokers. For years the Society subsisted wholly on these rentals and on members' dues. There were some hard times, as when during the depression beginning in 1837 the sheriff levied on building and contents, and the Society was saved only by the generosity of its more prosperous members. There were various plans to sell or exchange the property, but—fortunately, it seems now—they came to nothing. In 1890 a third story was added to accommodate the library. By 1934 all leases had been terminated, and after nearly a century and a half the Society finally occupied the whole of its building, with the main floor reorganized to its present plan. Meanwhile, however, the library had outgrown the available space and was moved to rented quarters across the street; after which the added top story was taken off to allow restoration of the building to its original shape and in architectural harmony with the other structures in Independence Square.

MEMBERSHIP

In 1834, when only local evening meetings were being held, somewhat more than half of the 200 American members lived within ten miles of the Society's quarters. The number of foreign members was however surprisingly large, 98, or almost a third of the total. The present membership is limited to 500 residents of the United States and 75 foreigners. These latter live in 19 countries.

The American membership is truly national in range, being drawn from thirty of our states. Fifty-nine members are from Philadelphia and its suburbs; the same number happen to live in California. New York is represented by 94, Massachusetts by 70, New Jersey by 39, Washington, D.C., by 34 members.

The membership is divided into four topical classes, which are roughly equal in size. Including foreign members, the numbers are: in Mathematical and Physical Sciences, 184; Geological and Biological, 161; Social Sciences, 123; Humanities, 109.

Anthropologists are eligible in two classes—a situation not unfamiliar to us. At present, Cole, Kluckhohn, Redfield, Schultz, and Spier are in the biological bracket, Kidder, Kroeber, and Lowie under the humanities.

FOREIGN MEMBERS

The list of foreign members of the Society is a roster of high eminence. In the physical sciences they have included Lavoisier, Priestley, both Herschels, Faraday, Humphry Davy, Mendeléyev, Helmholtz, Arrhenius, and Madame Curie. In earth and life sciences there were Linnaeus, Buffon, Alexander Humboldt, four Darwins over four generations beginning with Erasmus Darwin, de Candolle, Agassiz, Haeckel, Huxley, Pasteur, Virchow, and Pavlov. From public life there were Lafayette, Gladstone, and Beneš; from the humanities, Guizot, Mommsen, Ranke, and Renan in history, de Tocqueville, Spencer, Poincaré, and Croce in philosophy, Jacob Grimm, William Jones, Wilhelm Humboldt, and Isaac Taylor in philology.

Foreign anthropologists or their predecessors before there was an anthropology—and here, because of the way the record comes, we have of necessity to use the wider classification customary in America—have consisted of Broca, de Mortillet, Topinard, de Rosny, Lartet, and Hamy from France; Henry Maine, Lubbock-Avebury, Arthur Evans, and Arthur Keith from Britain; Blumenbach, Adelung, and Bastian from Germany; Sergi from Italy; Thomsen from Denmark and Retzius from Sweden; and Horatio Hale of Canada.

SOME RESIDENT MEMBERS

It would be wearisome to burden you with names of former Americans who have belonged

to the Society, except perhaps for two classes: men in public life and—anthropologists.

The former include Presidents Washington, Jefferson, Madison, Cleveland, Theodore Roosevelt, Taft, Wilson. The list evidences a certain selective discrimination, but not a partisan one. Others have included Alexander Hamilton, John Jay, Robert Fulton, Albert Gallatin.

The American anthropologists who have been members in their day I shall list without discrimination other than the alphabetic one. They were Boas, Brinton, Culin, Cushing, Dixon, Farabee, Gatschet, Holmes, Hooton, Hrdlička, MacCurdy, Otis Mason, Morley, Zelia Nuttall, Powell, Putnam, Rau, Sapir, Tozzer, Vaillant, and Wissler. To these should be added several who made important contributions to anthropology although their vocations were elsewhere. Such were Bowditch, Dall, Farrand, Hart Merriam, Clarence Moore, and Schoolcraft.

It is only fair to add that of the twenty-one first named, five were born outside the United States. After all, we are a people of polyglot and multiple ethnic orgins.

ARCADIA IN AMERICA

ERNEST HATCH WILKINS

President Emeritus of Oberlin College

PREFACE

THIS monograph is concerned mainly with the tracing of the extraordinary fortune in America of the title of the first famous Renaissance novel. It has overtones, however, that may perhaps serve to give to some readers a more complete comprehension of some phases of the Renaissance. If one could have met in the late sixteenth century with a group of well-informed European gentlemen and could have put to them the question "Which of the many achievements of this century do you believe to be the most important?" I surmise that among the answers given there would have been "The continuous exploration of the New World." And if one could have asked also the question "What art has in your opinion made the greatest advance in the course of the century?" I surmise that among the answers given would have been "The art of cartography."

Many persons have helped me in one way or another in the course of my work: my gratitude goes not only to those whose help is acknowledged in apposite footnotes but also to many others, especially to members of the staff of the Harvard University Library. I owe much, also, to the published writings of many scholars—especially to those of the late W. F. Ganong, without whose several pioneering articles on "Crucial Maps in the Early Cartography and Place-Nomenclature of the Atlantic Coast of Canada" the present study could hardly have been completed.

A variant form of this study, stressing elements that are thought to be of Italian rather than of American interest, is to be published in Italy.

I. THE CLASSIC ARCADIA

The actual Greek Arcadia was and is a mountainous region in the centre of the Peloponnesus.[1] Polybius, writing of its inhabitants in his *Histories* (Book IV, Chapters XX and XXI), says that they were famed for their virtue, piety, kindness, and hospitality; that they paid an extraordinary amount of attention to the study and practice of music, especially singing; and that they held frequent festivals and sacrifices, in which men, women, and children participated. He speaks of their life as hard and laborious, but does not specify their occupations. In his only reference to the physical characteristics of Arcadia he speaks of the cold and heavy air that hung over most of it.

There are slight references to Arcadia in Ausonius, Claudian, Horace, Juvenal, Lucretius, Ovid, Persius, and doubtless in other Latin poets. Ovid, in passages in Books I and II of the *Metamorphoses*, locates the myths of Syrinx and Callisto in Arcadia; but he does little more than tell his stories.

It was Virgil who created the enduring poetic concept of Arcadia. In the Tenth Eclogue the lovelorn Gallus, visited by Arcadian shepherds and divinities, says (ll. 31–36, 42–43, and 52–60):

> Yet you will be singing, O Arcadians, to your hills of this: alone Arcadians are skilled to sing. Ah how softly then may my ashes rest, if your pipe once may tell of my loves. And would God I had been one of you, and yours been the flock I kept or the ripe grapes of my vintage! . . . Here are chill springs, here soft meadows, O Lycoris: here the woodland: here with wasting time I too at thy side would waste away. . . . I will be gone . . . resolved in the woods, among the wild beasts' dens, to embrace endurance, and to cut my loves on the tender trees; with their growth you, O loves, will grow. Meanwhile I will range Maenalus amid the rout of Nymphs, or hunt the keen wild boar; no rigour of cold shall forbid me to encircle Parthenian glades with my hounds. Even now I think I pass among rocks and echoing groves, and delight to send the Cretan arrow spinning from a Parthian bow.[2]

Arcadian singing is referred to also in the Fourth, Seventh, and Eighth Eclogues.

No Latin poet other than Virgil, as far as I am aware, suggests that Arcadia was beautiful; and even Virgil, though his Arcadia is an attractive place, does not emphasize its beauty.

II. THE *ARCADIA* OF SANNAZZARO

The first book to bear the title *Arcadia*, the first book to be concerned mainly with Arcadian

[1] On its geography and history see Pauly-Wissowa, *Real-Encyclopädie der Classischen Altertumswissenschaft*, s.v. "Arkadia."

[2] From the translation of the Eclogues by J. W. Mackail, London, 1889.

life, the book that impressed the idea of Arcadia vividly and indelibly upon the mind of the Renaissance, was the *Arcadia* of Jacopo Sannazzaro, written chiefly in the years from 1480 to 1485. Its hero, a shepherd unfortunate in love, leaves Naples for Arcadia, where he finds shepherds dwelling in hardy simplicity, and lives for a time among them, taking part in their various activities; eventually he returns to Naples, only to find that the maiden he loved has died.

The proem of the novel opens with an arboreal simile, which begins thus:

> Sogliono il piu dele uolte glialti & spatiosi alberi negli horridi monti dela natura produtti: piu chele coltiuate piante: da dotte mani expurgate: negli adorni giardini ad riguardanti aggradare. . . .

The story itself opens with this passage:

> Giace nella sommita di Parthenio non humile monte dela pastorale Arcadia un dileteuole piano. . . . Oue . . . son forse dodici o quindici alberi: di tanto strana & excessiva bellezza: che chiunque li vedesse: giudicarebbe che la maestra natura vi si fusse con sommo diletto studiata in formarli. Li quali alquanto distanti: & in ordine non artificioso disposti: con la loro rarita: la naturale bellezza del luogo oltra misura annobiliscono.[3]

The *Arcadia* was immensely popular throughout the sixteenth century. An incomplete and unauthorized edition was published in 1501 and reprinted in 1502 and 1504; the first complete and authorized edition was published in 1504.[4] Thereafter, editions followed swiftly, in 1507, 1512, 1514 (two editions), 1515, 1516, 1519 (two editions), 1520?, 1521, 1522, 1525; and at least twenty other editions were published later in the century.[5]

In Italy no other novel rivaled the *Arcadia* in importance or influence in the course of the century; and it was soon known and imitated in other countries. Two of the most notable imitations repeat its name: the *Arcadia* of Sir Philip Sidney and the *Arcadia* of Lope de Vega, both written in the latter part of the century.[6]

III. THE VOYAGE AND REPORT OF GIOVANNI DA VERRAZZANO[7]

In the spring of 1524 the Florentine Giovanni da Verrazzano, who was then in the service of Francis I, King of France, explored the Atlantic Coast of North America from a point probably in what is now North Carolina to what is now Maine; and on his return he drew up a report for Francis. The official form of this report is not known to exist; but an Italian form, certainly antecedent to the official form (which would presumably have been in French), exists in two different texts, which may be called respectively the original text (of which there are two slightly differing varieties) and the revised text. The revised text is preserved in a single manuscript, which almost certainly belonged once to Paolo Giovio; it is often referred to (from the name of a later owner) as the Cellere manuscript; and it

[3] Both passages are quoted from the authorized edition of 1504. They may be rendered thus:

"The tall and wide-spreading trees produced by nature in wild mountains most usually give greater pleasure to those who behold them than do cultivated plants, pruned by skillful hands, in fair gardens. . . ." and

"On the summit of Parthenius, a not humble mountain of pastoral Arcadia, there lies a delightful plain . . . whereon . . . there are perhaps twelve or fifteen trees of such unfamiliar and excessive beauty that anyone seeing them would conclude that Mistress Nature had striven with the greatest delight to fashion them. Being at some distance from each other, and arranged in a not artificial order, with their rarity they ennoble immeasurably the natural beauty of the place."

[4] Fausto Nicolini, *L'arte napoletana del Rinascimento e la lettera di P. Summonte a M.A. Michiel*, 5–17, Naples, 1925.

[5] These statements rest on consultation of the printed catalogues of the Bibliothèque Nationale and the British Museum, and the Union Catalogue (a card catalogue) of the Harvard University Library.

[6] Francesco Torraca, *Gl'imitatori stranieri di Jacopo Sannazaro*, Rome, 1882, reprinted in his *Scritti vari raccolti a cura dei discepoli*, 109–193, Milan, 1928; and Michele Scherillo, in his edition of the *Arcadia*, ccxxxv–cclx, Turin, 1888.

[7] The basic study of this voyage and report is that of Alessandro Bacchiani, Giovanni da Verrazzano e le sue scoperte nell'America settentrionale (1524) secondo l'inedito codice sincrono Cellere di Roma, in Società Geografica Italiana, *Bollettino*, Ser. IV, X, Part II: 1274–1323, 1909. On pp. 1308–1323 Bacchiani prints the entire report, distinguishing the variants of its three texts. The passage quoted below appears on pp. 1313–1314. Bacchiani's study (including the report) is translated by E. H. Hall in American Scenic and Historic Preservation Society, *Fifteenth Annual Report*, 135–226, 1910. The Morgan MS of the report is reproduced by I. N. P. Stokes in his *The iconography of Manhattan Island* **2**: pl. 69–81, New York, 1916; and the voyage and report are discussed on pp. 11–17 and 169–171 of the same volume, and in **4**: 14–19, 1922. See also H. F. Covington, The discovery of Maryland, or Verrazzano's visit to the Eastern Shore, in *Maryland Hist. Mag.* **10**: 199–217, 1915; W. F. Ganong, Crucial maps in the early cartography and place-nomenclature of the Atlantic Coast of Canada (III), in The Royal Society of Canada, *Proc. and Trans.* 3rd ser., **25**, Sect. II: 169–203; and Jacques Habert, *When New York was called Angoulême*, New York, 1949.

is now in the Pierpont Morgan Library. This text, as thus preserved, has insertions and notes in Verrazzano's own hand, some of them hard to decipher. The most notable difference between the original text and the revised text is that whereas the original text contains no place names the revised text, in its notes, contains twenty names given by Verrazzano to regions or various natural features along the coast.

From Verrazzano's report it appears that his first landing was made near what is now called Cape Fear; and that his second landing (not counting an episode in which a single sailor went ashore) was made at a point on the Accomack peninsula—the peninsula, known also as the Eastern Shore, that lies to the east of what is now called Chesapeake Bay, and now comprises two counties of Virginia, part of Maryland, and Delaware. It seems probable, on the whole, that the landing was made in what is now Worcester County, Maryland.[8]

The account of this region as contained in the original text of the report is in part as follows:

La terra del sito, bontà et belleza, è come l'altra; le selve rare; di vario genere d'alberi piena, ma non di tanto odore, per esser più septentrionale et fredda. Vedemmo in quella molte vite da la natura prodotte, quali alzando, s'avvoltano a li alberj, come ne la Cisalpina Gallia costumano: quali, se dagli agricoltori havessino el perfetto ordine di cultura, sanza dubio, produrebbono optimi vini, perchè più volte il frutto di quelle veggiendo suave et dolce, non dal nostro differente. Sono da loro tenute in stimatione, imperochè per tutto dove nascono lievano li arbucelli circumstanti a causa il frutto possino germinare. Trovamo rose silvestre, viole et lilij et molte sorte d'herbe et fiorj odoriferi da nostrj differenti. . . . Essendo in questa dimorati tre giorni, surti a la costa, per la rarità de' porti deliberammo partire scorrendo sempre il lito.[9]

After the word *lito,* Verrazzano in the revised text calls for the insertion of a note that begins: *quale batezamo Archadia per la bellezza de li arbori*—"which we named Archadia because of the beauty of the trees." The page in question is reproduced herewith as figure 1, with the kind permission of the Pierpont Morgan Library.

The name *Arcadia* (spelled this time without the *h*) occurs also in a note, written on the last leaf of the manuscript, that begins thus: *Ne l'Arcadia trovamo un homo, el quale veneva al lito per vedere che gente eramo* . . . "In Arcadia we found a man who came to the shore to see what sort of people we were."

In view of the place held in Italian interest and imagination at the time by Sannazzaro's *Arcadia,* and in view of Verrazzano's specific statement that he called the region *Arcadia* "per la belleza de li arbori," it is clear that he must have derived the name *Arcadia* from his memory of Sannazzaro's romance.

To all the land that he discovered Verrazzano gave the name *Francesca,* in honor of Francis I. Among his other names are *Campo di Cedri* (for a region near the point of his first landing), [*Isthmo*] *Verazanio* (applied, almost certainly, to the string of narrow sand islands running from Cape Lookout northward to Cape Henry), *Costa di Lorenna* (a reference to Lorraine), *S. Polo* (a hill), *Angoleme* (applied to the region around the mouth of the Hudson, also in honor of Francis), *Aloysia* (an island—probably Block Island—named in honor of Francis' mother, Louise of Savoy), *Refugio* (Newport and the surrounding region), and *Le III Figlie di Navarra* (three islands off the coast of Maine).

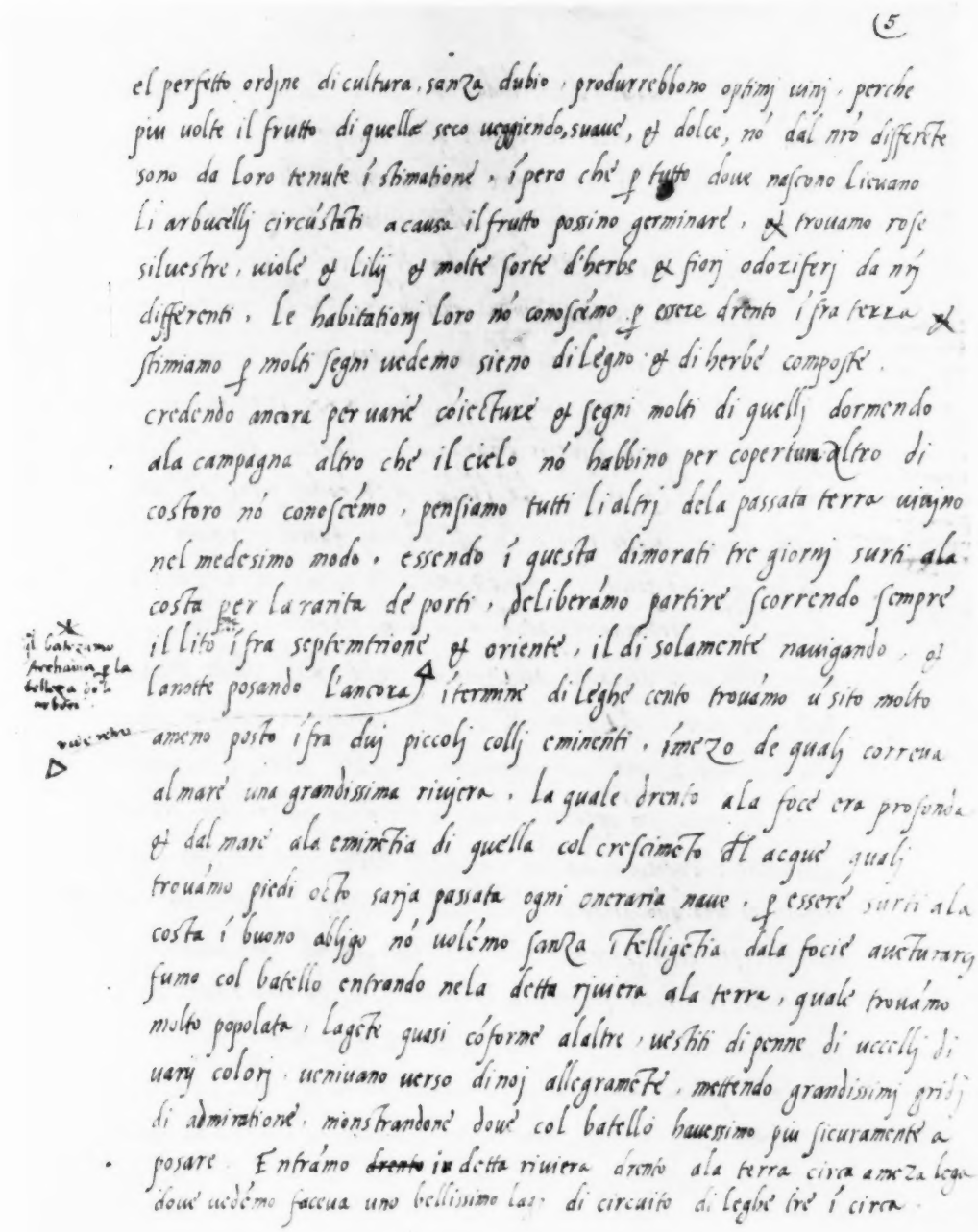
Verrazzano must have prepared a map of some sort for submission with his report, and copies of that map were doubtless made. Neither that map itself nor any copy of it is known to exist;[10] but

[8] See Covington, 207–211.

[9] That is:

"The land of this region, as regards its goodness and its beauty, is like the other [i.e., like that seen farther south]; it is not thickly wooded; it is full of trees of various kinds, but they are not so fragrant, since it is farther north and colder. Here we saw many vines growing wild, which as they shoot up twine around the trees, as they do in Northern Italy: these vines, if they had skillful care from cultivators, would doubtless produce excellent wines, as we found their grapes to be sweet and soft, not unlike our own. The vines are valued by the natives, since wherever they spring up the bushes are cleared away so that they may have a chance to develop. We found wild roses, violets and lilies and many kinds of herbs and fragrant flowers different from ours. . . . Having stayed here for three days and gone out to the coast, we decided, because of the scarcity of good harbors, to set sail, holding close to the shore."

[10] Two passages in Hakluyt refer ostensibly to a map made by Verrazzano. In his preface to the *Divers Voyages* Hakluyt writes: "Secondly that Master John Verarzanus, which had been thrise on that coast, in an olde excellent mappe which he gave to Henrie the eight, and is yet in the custodie of master Locke, doth so lay it out, as it is to be seene in the mappe annexed to the end of this booke, being made according to Verarzanus plat"; and in his *Discourse on Western Planting:* "Tenthly there is a mightie large olde mappe in parchemente made as yt should seme by Verarsanus, traced all along the coaste from fflorida to Cape Briton



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el perfetto ordine di cultura, sanza dubio, produrrebbono optimi uini, perche
piu uolte il frutto di quelle seco ueggiendo, suaue, et dolce, no' dal nro' differente
sono da loro tenute i stimatione, i pero che' p tutto doue nascono liceuano
li arbucelli circustanti a causa il frutto possino germinare, et trouamo rose
siluestre, uiole et lilij et molte sorte d'herbe et fiori odoriferi da nri
differenti. Le habitationi loro no' conoscemo p essere drento i fra terra
stimiamo p molti segni uedemo sieno di legno et di herbe composte.
credendo ancora per uarie coiecture et segni molti di quelli dormendo
ala campagna altro che' il cielo no' habbino per copertura altro di
costoro no' conoscemo, pensiamo tutti li altri dela passata terra uiuino
nel medesimo modo, essendo i questa dimorati tre giorni surti ala
costa per la rarita de porti, deliberamo partire scorrendo sempre
il lito i fra septemtrione et oriente, il di solamente nauigando, et
la notte posando l'ancora i termine di leghe cento trouamo u' sito molto
ameno posto i fra dui piccoli colli eminenti, i mezo de quali correua
al mare una grandissima riuiera, la quale drento ala foce era profonda
et dal mare ala eminetia di quella col crescimeto de acque quali
trouamo piedi octo sarja passata ogni oneraria naue, p essere surti ala
costa i buono abbigo no' uolemo sanza intelligetia dala gente auicinarci
fumo col batello entrando nela detta riuiera ala terra, quale trouamo
molto popolata, lagete quasi coforme alaltre, ueshti di penne di uccelli di
uarij colorj, ueniuano uerso di noj allegramete, mettendo grandissimi gridi
di admiratione, monstrandone doue col batello hauessimo piu sicuramente a
posare. Entramo ~~drento~~ in detta riuiera drento ala terra circa mezza lega
doue uedemo faceua uno bellissimo lago di circuito di leghe tre i circa.

FIG. 1. Page 5 of the Morgan Manuscript.

the two maps that are next to be considered cannot possibly have been based, for the outline and nomenclature of the region explored by Verrazzano, on anything but a map made by him (or on a copy or copies of it). From these two maps also it appears that Verrazzano's lost map contained many more than the twenty names that occur in the revised form of his report; also that some of the names that appeared on his map (or on a copy or copies of it) were difficult to decipher. Presumably some of the names were in French forms—especially those reflecting French place names or honoring French persons. Presumably, also, the map covered only the portion of the coast that had been explored by Verrazzano.

IV. EARLY VERRAZZANIAN MAPS[11]

In 1527 the Genoese cartographer Vesconte de Maggiolo made a map of the world which in its appropriate portion reflects the discoveries of Verrazzano.[12] For the coast explored by Verrazzano Maggiolo has a coast line which, though inaccurate, is clearly not imaginary, and can therefore have been based only on Verrazzano's map; and for the whole region concerned Maggiolo has nearly fifty names, all or most of which were certainly or presumably derived from Verrazzano's map. Fourteen (including *Francesca* for the whole region) are names that appear in Verrazzano's report; and the names that appear on Maggiolo's map but not in Verrazzano's report are of the same types as the names that do appear in that report. Some of them honor French personages or recall French place names, and others recall Italian place names (among them are the specifically Florentine *lorto de rucelay* [L'Orto de' Rucellai], *Saminito* [San Miniato], *S. Gallo*, and *Caregi*).

The name *Arcadia* is one of the six names that appear in Verrazzano's report but do not appear on Maggiolo's map. His omission of these names was presumably due, in some cases, at least, to difficulty in deciphering names written by Verrazzano himself or by a copyist. Some of the names that appear in Verrazzano's report appear on Maggiolo's map in distorted forms: *Cedri* as *scrui*, *Lorenna* as *laurorcno*, *S. Polo* as *poll*, and *Le III Figlie di Navarra* as *Figole de nauarin*. Certain other names in Maggiolo's map seem to reflect an unsuccessful attempt at decipherment, such as *pla de calmi*, *firloi*, *la scarides*, *carpoes*, *quoachi*, and *Gibercas*.

In 1529 Verrazzano's brother Gerolamo made a map of the world which in its appropriate portion reflects the discoveries of Giovanni.[13] For the region with which we are concerned Gerolamo has more names than Maggiolo: his names include three of the six names—but not the name *Arcadia*—that appear in Giovanni's report but not on Maggiolo's map;[14] most but not all of Maggiolo's names; and several additional names.[15] Some of

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w^th^ many Italian names" (*The original writings & correspondence of the two Richard Hakluyts*, ed. by E. G. R. Taylor **1**: 177 and **2**: 287, London, 1935). But the map "annexed to the end of" the first edition of the *Divers voyages* (1582) shows no trace of Verrazzano's nomenclature.

[11] I am very greatly indebted to Mrs. Kirk Bryan, in charge of the Map Room in the Harvard University Library, for her most cooperative helpfulness in all matters relating to the many maps that I have found it necessary to examine during the preparation of this monograph.

[12] Reproduced by E. L. Stevenson in his *Maps illustrating early discovery and exploration in America, 1502–1530*, No. 10, New Brunswick (New Jersey), 1903, and discussed briefly in Stevenson's *Text and key maps* (1906), published to accompany his collection. Reproduced in part by Stokes, **2**: pl. 12, and discussed briefly on p. 13. Reproduced in part by Ganong, fig. 34, and discussed on pp. 174–194. On Maggiolo see M. A. P. d'Avezac, Atlas hydrographique de 1511 du Génois Vesconte de Maggiolo, in *Annales des voyages de la géographie de l'histoire et de l'archéologie*, 20–32, July, 1870.

[13] Reproduced by Stevenson, *Maps . . . .*, No. 12, and discussed briefly in his *Text and key maps*. Reproduced in part by Stokes, **2**: pl. 13, and discussed briefly on p. 13. Reproduced in part by Ganong, fig. 35, and discussed on pp. 174–194. Reproduced by Roberto Almagià in *Monumenta cartographica vaticana* **1**: pls. xxix–xxvi, Città del Vaticano, 1944, and discussed on pp. 53–55.

[14] Ganong (pp. 81 and 203) suggests that the name *lamacra*, which appears on Gerolamo's map but not on Maggiolo's, may be a distortion of *larcadia*. This suggestion, however, is not valid: there is a small but well-known river in Tuscany called *La Macra*.

[15] To the entire region, called *Francesca* by Giovanni and by Maggiolo, Gerolamo gives three names: his main inscription reads *Nova Gallia sive Ivcatanet*, and an added note reads: *Verrazana siue noua gallia quale discopri 5 anni fa giouanni da verrazano fiorentino per ordine et comandamento del Chrystianissimo Re di francia*—"Verrazana or New Gaul which Giovanni da Verrazano of Florence discovered five years ago by the order and command of the Most Christian King of France." Gerolamo seems to have been determined to get the largest possible number of names onto his map, and to have made up his addenda in various ways—partly by new inventions, and partly by using a single name twice, or even thrice, at different points; see Ganong, pp. 190–191. The same tendency toward a multiplication of names appears in the work of some other early cartographers dealing with little-known regions.

FIG. 2. Gastaldi's *Tierra Nueva*.

Gerolamo's additional names are of the same types as those that appear in Giovanni's report (among them the specifically Florentine *m. morello*). Some of the names that appear on both maps and some of Gerolamo's additional names appear to reflect a difficulty in decipherment.

Among other maps that are datable before 1548 there are a few that are clearly influenced, directly or indirectly, by Giovanni's map or by one of the two maps just considered; but no one of these maps shows more than a very few names for the region with which we are concerned, and no one of them shows the name *Arcadia*.[16]

[16] See Stokes, **2**: 16–17 and pl. 17; Ganong, 194–200; Habert, 95–96; and Marcel Destombes, Nautical charts attributed to Verrazzano (1525–1528), in *Imago mundi* **11**: 57–66, 1954. The lower half of Ganong's p. 197 and the upper part of his p. 198 are erroneous in some respects.

After this point, when the name Verrazzano is used without a forename it refers always to Giovanni da Verrazzano.

V. GASTALDI'S *TIERRA NUEVA*

The first New World map to show the name *Arcadia*, reproduced herewith as figure 2, is one of the sixty two-page maps made by Giacomo Gastaldi, the most eminent Italian cartographer of the sixteenth century,[17] for the first edition of the first Italian translation of the *Geografia* of Ptolemy, published in Venice in 1548.[18]

[17] On Gastaldi see three works by Stefano Grande: *Notizie sulla vita e sulle opere di Giacomo Gastaldi*, Turin, 1902; *Le carte d'America di Giacomo Gastaldi*, Turin, 1905; and Le relazioni geografiche fra P. Bembo, G. Fracastoro, G. B. Ramusio, G. Gastaldi, in Società Geografica Italiana, *Memorie* **12**: 93–197, 1905.

[18] The title page bears the date 1548. The publisher was Giovan Battista Pedrezano. The book opens with a dedicatory letter by Gastaldi (addressed to Leone Strozzi), dated 2 January 1548, and continues with an unsigned address "A li lettori." The first of the two main parts of the book contains the translation, followed by a colophon, on p. 216^r, in which the date of printing

Gastaldi's *Tierra Nueva*, the third of five maps devoted to the New World, is located between pp. 56 and 57, and his statement about it appears on p. 56[r].[19]

The name *Larcadia* (the *L* is of course the definite article) is applied to a region corresponding to that to which it had been applied by Verrazzano in his report. For the rest of the coast that had been explored by him six names appear: *Angoulesme, Flora, le paradis, Brisa* (a deformation of *Aloysia* or *Luisa*), *p°: Real*, and *p°: Refuge*. Four of these seven names, in the forms *Archadia* (or *Arcadia*), *Angoleme, Aloysia*, and *Refugio* occur in Verrazzano's report; six of them, *Anguileme, Flora, el paladiso, luisa, p. reale*, and *Refugio*, appear on the Maggiolo map; and three of them, *angolemme, Luisa*, and *refugio*, appear on the map of Gerolamo da Verrazzano. In Gastaldi's map the names *Angoulesme, le paradis, Real*, and *Refuge*, are definitely French in form. His *p°: Refuge* (Newport and the surrounding region) is directly adjacent to his *Tierra de los broton*, which is itself the point of mainland nearest to *c. breton*.

Gastaldi does not at any point indicate the source or sources upon which he based this map. It is certain that the portion of the map containing the seven names that have just been quoted must have been derived directly or indirectly from Verrazzano—that is, from some form or copy of his report, or from his lost map or a copy of it. Negatively, it cannot have been derived from the extant revised form of the report, since that form lacks names corresponding to *Flora, le paradis*, and *p°: Real;* and it cannot have been derived from either the Maggiolo map or the map of Gerolamo da Verrazzano, since both those maps lack the name *Arcadia* and show an extensive coast line and many place names to the east and north of *Refugio* before reaching a point corresponding to Gastaldi's *Tierra de los broton*. Positively, it is certain, from the French name-forms concerned, that the source from which Gastaldi derived the seven names in question came from France; it may have been a French form or forms of Verrazzano's report or of his lost map or both, or a French derivative or derivatives of that report or that map or both.[20]

Gastaldi's map as a whole is obviously derived, directly or indirectly, from two different and incongruous sources, one for the coastal region of its western half, and one for its eastern half plus the name *Tierra del Bacalaos*. The juxtaposition gives the impression that the entire region depicted to the west of *Tierra de los broton* is adjacent to the eastern point of the mainland; and this impression is strengthened by the fact that the seven Verrazzanian names all fall below the general heading *Tierra del Bacalaos*, which is necessarily associated with the easternmost coast. Such an impression, as will appear below, in Section VII, certainly prevailed among several later cartographers who were influenced directly or indirectly by Gastaldi's map.

Whatever the origin of Gastaldi's source material, it is highly probable that it reached him through Ramusio, with whom he was intimately associated as early as 1546;[21] and it is quite possible that Ramusio himself had received it from Fracastoro, who was intensely interested in the exploration of the New World, and had gathered material relating to it.[22]

is given as October 1547. The second main part contains Gastaldi's maps, each of which is preceded (and, if necessary, followed) by a leaf bearing a brief statement about the map in question: these leaves are numbered from 1 to 60. The book concludes with a 64-leaf index.

[19] Gastaldi explains the name *Tierra del Bacalaos* (a name that occurs on many other early maps) by saying that the shores of this region were discovered by Breton fishermen, who there catch cod, and therefore call the whole region "the Land of the Cod." The name *Nurumberg*, which Gastaldi does not discuss, had first appeared on the map of Gerolamo da Verrazzano in the form *Oranbega*, inserted not as a regional name but as a local name in a series of crowded names applied, apparently arbitrarily, to a coast corresponding roughly to the coast of Maine (it may be that Gerolamo's form *Oranbega* was due to an entry on Giovanni's map that Gerolamo could not decipher). In other sixteenth-century maps it appears in several different forms (including the form *Norumbega*), and is applied to different regions. While the origin of the name remains uncertain, it seems probable that it was actually a name used by the Indians who lived in the vicinity of Narragansett Bay. It is to be noted, in this connection, that Verrazzano spent two weeks in the Narragansett Bay region, and that there and there only he had extensive friendly contacts with the Indians. For a discussion of the name and its applications see Ganong, 199–202.

[20] The names *Larcadia, Flora*, and *Brisa* may well have been retained in Italian forms even in a French report or map. They are proper names, unlike *le paradis* and *Refuge;* and they are not French place names, like *Angoulesme*.

[21] Grande, *Le carte d'America*, 71, and Le relazioni geografiche, 187–188. On Ramusio see G. B. Parks, The contents and sources of Ramusio's *Navigationi*, in New York Public Library, *Bulletin* **59**: 279–313, 1955, and Ramusio's literary history, in *Studies in Philology* **52**: 127–148, 1955.

[22] See the introductory discourse, addressed to Fracas-

The maps made by Gastaldi for the Ptolemy of 1548 were imitated, on a larger scale but with no substantial alteration, for the first edition of a new Italian translation of the *Geography* by Girolamo Ruscelli, published in 1561; and the maps of that edition reappear, with no substantial alteration, in an edition of the Latin text published in 1562 and in editions of Ruscelli's translation published in 1564 and in 1574. The name *Larcadia* accordingly appears, in its original position, on the *Tierra Nueva* maps in these four editions.[22a]

Gastaldi's *Tierra Nueva* was clearly the source of the corresponding portion of a map made about 1560 by an unknown Italian mapmaker (it was formerly attributed to Battista Agnese), on which the name *arcadia* appears in the same position as in Gastaldi's map and is followed, to the east, by the names *Angoulesme, paradis, Brisa, pᵒ. Real, pᵒ. del refuge,* and *C. Breton* (Gastaldi's *Flora* is omitted), with the name *Terra de Nurumbega* appearing inland and to the northwest of the names *pᵒ. del refuge* and *C. Breton.*[23]

VI. THE VOYAGE OF ESTEVAN GOMEZ AND MAPS BASED THEREON

In 1525—the year after that in which Verrazzano had made his voyage—Estevan Gomez, in the service of Spain, explored the portion of our coast that lies between Nantucket Island and the southern shore of New Brunswick; and to various natural features in this region he in his turn gave names. Neither his report nor any accompanying map is extant; but several maps were soon made which, for the region concerned, were based directly upon his data. Among the names that appear (in slightly varying forms) upon these maps are *C. de Santiago* (Cape Cod), *b: de s. cristoual* (Massachusetts Bay), *b: de s. antonio* (Boston Harbor), *R. de buena madre* (the Merrimac), *Rio seco* (perhaps the Saco), *montanas* (which presumably reflects a distant view of the White Mountains), *Rio de las gamas* (the Penobscot), *golfo* (probably Frenchman's Bay), and *R: de la buelta* (the St. John).[24]

Among the later maps based upon data derived from Gomez is one by Nicolaus de Nicolay, of the Dauphiné, an Italian form of which, entitled *Navigationi del mondo novo,* was issued in Venice in 1560.[25] The nomenclature of this map for the region concerned is derived from the Gomez nomenclature, except that Cape Cod is called *C. de S. Maria* and that the regional name *Tiera de Bacalaos* appears at the top of the map: these two names had appeared on Gastaldi's *Tierra Nueva,* on which, however, the name *c: de s. maia* had appeared at a point south of his *Larcadia.* The name *Tiera de los Bretons* appears—as on some of the earlier maps based upon data derived from Gomez—as a regional name below the name *Tiera de Bacalaos.*

VII. THE NAME *ARCADIA* MOVES NORTHWARD

On six maps that are certainly or probably of the third quarter of the century the name *Arcadia* appears as a regional name for southern portions of Maine and of the mainland to the east. These maps do not account for Nova Scotia; their coast line to the east of Maine shows various promontories, but no great peninsula.

Between 1560 and 1565, probably, the Venetian Ferrando Bertelli, who (on a later map) calls himself a *libraro* (that is, a bookseller and publisher), issued the map of the Atlantic Ocean and its surrounding lands which is reproduced herewith as figure 3.[26] On this map the name *Larcadia* appears as a regional name below the name *Nueva Francia.*

toro and dated 20 June 1553, in Ramusio's *Terzo volume delle Nauigationi et viaggi nel quale si contengono le Nauigationi al Mondo Nuouo,* f. 5ᵛ, Venice, 1556.

[22a] See H. N. Stevens, *Ptolemy's geography: a brief account of all the printed editions down to 1730,* London, 1908, and Angela Codazzi, *Le edizioni quattrocentesche e cinquecentesche della "Geografia" di Tolomeo,* Milan, 1950. The *Tierra Nueva* map and the maps most closely associated with it are replaced, in Latin editions of 1596, 1597, and 1608, and in Italian editions of 1598 and 1621, by a new general map of North and South America on which the name *Arcadia* does not appear. I have examined, in the Harvard University Library, copies of all the editions of Ptolemy referred to in this study.

[23] Reproduced in Konrad Kretschmer, *Die Entdeckung Amerika's in ihrer Bedeutung für die Geschichte des Weltbildes, Atlas,* pl. XXIII, Berlin, 1892, and in Stokes, **2**: pl. 17. For a discussion of the authorship of this map see H. R. Wagner, The manuscript atlases of Battista Agnese, in The Bibliographical Society of America, *Papers* **25**: 42–45, 1931.

[24] This paragraph is based entirely on Ganong (IV), in *Proceedings . . .* **26**, Sect. II: 125–179, 1932.

[25] Reproduced in Nordenskiöld, *Periplus, an Essay on the Early History of Charts and Sailing-Directions,* trans. from the Swedish by F. A. Bather, pl. XXVII, and discussed on p. 72, Stockholm, 1897.

[26] From an original copy in the Harvard University Library. This map is reproduced in *Remarkable maps of the XVᵗʰ, XVIᵗʰ and XVIIᵗʰ centuries,* Portfolio I, ed. by C. H. Coote, No. 10, and discussed briefly on pp. i–ii, Amsterdam, 1894. It is reproduced also in Nordenskiöld, *Periplus,* 183, and discussed on pp. 72–73.

FIG. 3. Bertelli's map of 1560–1565.

The general source of this map, as both Coote and Nordenskiöld point out, is the map of Nicolaus de Nicolay. Retaining in general the nomenclature of that map for the region concerned, Bertelli varies from it in a few minor respects, in the substitution of the regional name *Nueva Francia* for the regional name *Tiera de Bacalaos*, and in the substitution of *Larcadia*, as a regional name, for the regional name *Tiera de los Bretons*.

The northward transfer of the name *Larcadia* on this and the other maps concerned is clearly due to the impression given by Gastaldi's map—as noted above, in Section V—that the entire region depicted on that map to the west of *Tierra de los broton* is adjacent to the eastern point of the mainland, an impression strengthened by the fact that on that map *Larcadia* and its other Verrazzanian names all fall below the general heading *Tierra del Bacalaos*.[27]

Bertelli, in particular, may well have noted that in Gastaldi's map *Larcadia* appears as a regional name next to the north but well to the north of *C: de s. maia;* and the fact that on the map of Nicolaus *C. de s. maria* appears at a point well to the north of the point at which it appears on Gastaldi's map may have led Bertelli to place it well to the north of his *C. de S. Maria* as the first regional name north of that cape.

The name *Larcadia* appears as a regional name in the same position, and below the name *Nueva Franza*, on a map engraved by Paolo Forlani entitled *Universale descrittione di tutta la terra conosciuta fin qui*, issued by Bertelli in 1565.[28]

[27] This explanation repeats that of Ganong, who says in his "The Origin of the Place-names Arcadia and Norumbega," in *Proceedings . . .* **11**, Sect. II: 106, 1917: "Gastaldi's map is a map of *Tierra Nueva*, practically New France, and it has Larcadia near its western part, while it happens that the entire topography is so greatly condensed from Larcadia to Cape Breton as to make that region seem like the coast of Nova Scotia. Indeed, so competent and careful a student as Kohl, in his well-known work on the early cartography of Maine, took the Angoulesme of a nearly identical map by Gastaldi to represent Passamaquoddy Bay, in which case *Larcadia* would have fallen in eastern Maine."

[28] Reproduced in *Remarkable maps*, Portfolio IV, 1897, and discussed by Giuseppe Caraci in his *Tabulae*

It appears as a regional name in the same position, and below the name *Nova Francia*, on an undated and not closely datable map by Fernandez Simao.[29] It appears as a regional name to the right of the name *Nova Franza* on three other maps: a map by Bolognino Zaltieri entitled *Il disegno del discoperto della nova Franza,* printed in Venice in 1566;[30] on a globe of 1570 (the name in this case is *Arcadia*, without the *L*) made by Francesco Basso;[31] and on a map entitled *Mondo nuovo* printed by Thomaso Porcacchi in his *L'isole piu famose del mondo,* published in Venice in 1572.[32]

VIII. THE NAME *ARCADIA* APPLIED TO NOVA SCOTIA

There is reproduced herewith, as figure 4, an anonymous and undated map, published about

geographicae vetustiores in Italia adservatae **1**: 6–10, Florence, 1926.

[29] Reproduced in Ganong, Crucial maps (VII), in *Proceedings . . .* **29**: fig. 106, 1935, and discussed on pp. 122–123. See however Armando Cortesao, *Cartografia e cartógrafos portugueses dos séculos XV e XVI*, II (Lisbon, 1935), 264. Simao can hardly have been the pioneer in the northward transfer of the name *Larcadia*, since his map shows none of the other Verrazzanian names concerned. On this map a representation of the St. Lawrence intervenes between the names *Nova Francia* and *Larcadia*, and the name *Larcadia* is followed by the letters *Pro* (an abbreviation for *Provincia*).

[30] Reproduced in Kretschmer, pl. XIX. This map is preserved in the Lafreri Atlas, on which see Nordenskiöld, *Periplus*, 118–122. On this map and on the Porcacchi map the name *Larcadia* appears below the regional name *Canada Pro.*

[31] Reproduced in part in Kretschmer, pl. XXIX, and discussed on p. 436. On this map the name *Terra Anorumbega* intervenes between the names *Nova Franza* and *Larcadia.*

[32] P. 101.

FIG. 4. An anonymous map of about 1585.

1585 though probably made somewhat earlier, which is the first map on which Nova Scotia appears in anything like its true peninsular form, and the first map on which the name *Arcadia* is applied specifically to Nova Scotia. It is one of nine sheets that together make up a large map of North and South America.[33] It has been thought that this map influenced the map by Forlani mentioned in the preceding Section, and on that ground this map has been dated as prior to 1574. This, however, is by no means certain: it seems to me equally possible that this map may have been influenced by the Forlani map, and that it may therefore have been made after 1574 and at a time somewhat closer to its publication about 1585.

IX. THEVET'S *ARCADIE*

The French form *Arcadie* makes its first appearance, as used with reference to the region concerned, in André Thevet's *La Cosmographie Universelle*, published in Paris in 1575. In Book XXIII, Chapter III, a chapter entitled *De la terre de Canada & Baccaleos & de plusieurs riuieres de la coste de Norombegue*, Thevet writes:

> Entrant en mer du costé du Nord, bien deux cens lieuës, les Isles qui l'auoisinent, sont en si grand nombre que rien plus, & fort grandes, soit dans le goulphe, qui est entre l'Arcadie & le Promontoire dit & nommé par moi Angoulesme, à cause du lieu de ma naissance, ou celles qui sont pres de Flora et de Paradis, ou celles qui sont enfermees dans le port de refuge, ou qui puis apres s'estendent le long de l'Ocean. . . .

and again, in Chapter V, after speaking of the perilous rocks in the region of *Terre-neufve:*

> il vous fault faire plus de trois cens lieuës, pour euiter ce peril, & contourner toute ceste ceinture, soit prenant la volte du Nord par le costé de Labrador, ou la route de l'Ouest, comme qui iroit à la Floride, & puis doubler au Cap de l'Arcadie iusques au Cap Breton.[34]

Thevet, as Ganong points out, "had no original knowledge of this region, and must have taken the word from some map."[35] He was, furthermore, quite unreliable—as instanced by his claim to have named *Angoulesme*. The fact that his uses of the name *Arcadie* occur in the course of his discussion of Canada indicates sufficiently that he thought of it as applicable to a northern region. His first use of the name, in which it occurs in connection with *Angoulesme, Flora, Paradis,* and *port de refuge,* is clearly based on Gastaldi's map, which he appears to have misinterpreted in the same way as the mapmakers referred to in Section VII of this study. His *Cap de L'Arcadie* is a product of either his confusion or his invention.

X. FISHERMEN, FUR-TRADERS AND LIEUTENANTS GENERAL

During the second half of the sixteenth century, and especially in its last three decades, French fishermen plied the waters of New France and French fur traders were active along the St. Lawrence and to some extent elsewhere in New France: both fishermen and fur traders came mainly from Brittany and Normandy. French control of the entire region was, however, menaced by the increasing activities of English and other fishermen and fur traders, and by the proximity of New England; and the French government came to the conclusion that its control could be preserved only if French colonies should be established there, and that colonies could in fact be established only if the men commissioned to establish them should be given trading monopolies.[36]

A broad colonizing commission was accordingly given on 12 January 1598 to the Marquis de la Roche; but his one small settlement on Sable Island came quickly to a disastrous end.[37]

[33] Reproduced in *Remarkable maps* **1**: pl. 13, and discussed by Coote on p. ii. Reproduced in Caraci, **2**: pls. XXXIV and XXXV, and discussed on pp. 37–48, 1927. Reproduced by Ganong, Crucial maps (VI), in *Proceedings . . .* **28**: fig. 95, and discussed on pp. 262–264, 1934. Discussed also by R. Almagià in his Su alcuni importanti cimeli cartografici conservati a Venezia, in *Atti del VIII Congresso Geografico Italiano* **2**: 295–302, 1921. No one of these scholars mentions the fact that Nova Scotia has here its peninsular form, or that the name *Arcadia* is here applied specifically to the peninsula.

[34] Ff. 1009[b] and 1018[a–b]. I have corrected an obvious misprint in the word *prenant*.

[35] An organization of the scientific investigation of the Indian place-nomenclature of the maritime provinces of Canada, in *Proceedings . . .* **9**: 446, 1915.

[36] Edouard Gosselin, *Nouvelles glanes historiques normandes puisées exclusivement dans des documents inédits*, 7–9, Rouen, 1873; Charles and Paul Bréard, *Documents relatifs à la Marine normande . . .* 50–59, 73, 75, 78, and 83–87, Rouen, 1889; H. P. Biggar, *The early trading companies of New France*, 18–37, Toronto, 1901; David Allison, *History of Nova Scotia* **1**: 31–35, Halifax, 1916.

[37] Gosselin, 10–14; Bréard, 60–65 and 73–84; Biggar, 38–42; and W. I. Morse, *Acadiensia nova (1598–1779)* **2**: 24–39, London, 1935. Copies of his Commission and of two related documents were printed in Paris in 1609 by Marc Lescarbot in his *Histoire de la Nouuelle France;* they appear on pp. 434–449 of that edition, and on pp. 483–488 of *The history of New France of Marc Lescarbot,*

Among the fur traders was Pierre Chauvin, Sieur de Tonnetuit—a Huguenot born at Dieppe but living at Honfleur. Since about 1594 his vessels had traded annually to the St. Lawrence; and on 22 November 1599, according to Fournier, "le Capitaine Chauuin Sieur de Touthuict fut declaré Lieutenant general pour le Roy au pays de Canadas, costes de Lacadie & autres de la nouuelle France pour 10. ans." [38]

In the spring of 1600 Chauvin sailed to New France, taking with him some fifty colonists, whom he left to wintry hardship and fatality at Tadoussac—where the Saguenay flows into the St. Lawrence. Pierre du Gua, Sieur de Monts (who was soon to undertake a colonizing enterprise of his own, as will presently appear), accompanied Chauvin on this expedition.[39]

ed. and trans. by W. L. Grant, II, Toronto, 1911. These documents do not contain the name *Arcadie* or any abbreviation thereof.

[38] Georges Fournier, *Hydrographic contenant la théorie et la pratique de toutes les parties de la navigation*, 255, Paris, 1667. The passage quoted occurs in Chap. XXI of Book VI, which is entitled "Memoires de L'Amirauté et Police Navale de France" (the page headings read "Memoires de la Marine de France"). No copy of Chauvin's Commission is known to exist. Dr. Raffaele de Cesare, who has carried on research in Paris on my behalf in a most cooperative and efficient manner, reports that he has found no copy in the Registres du Parlement.

[39] Alfred Ramé, *Documents inédits sur le Canada*, Deuxième série, 12–21, Paris, 1867; Gosselin, 17–20; Bréard, 66–73, 75, 78, and 86–92; Biggar, 42–46; and Allison, 36–37.

XI. LEVASSEUR'S *CADIE*

There is reproduced herewith, as figure 5, part of a map of the coasts of the Atlantic Ocean made in Dieppe in 1601 by Guillaume Levasseur: this is the earliest map to show a reduced form of the name.[40]

The two regional names, *Coste de Cadie* and *Nouuelle France*, obviously correspond, though in French forms and with an arbitrary shift in their relative positions, to the names *Larcadia* and *La nova Franza* as found on the Bertelli map and on other maps referred to in Section VII.

The St. Lawrence portion of the map shows several (still surviving) names that had not appeared on any earlier extant map. As to Levasseur's source for these names Ganong writes: "Apparently the only possible source was the French navigators resorting to the region during the years 1580–1600" and "it would be wholly natural that the one who supplied him with these names would have done so in the form of a sketch

[40] This map exists in manuscript only, in the archives of the Service Hydrographique de la Marine, where it bears the number 116-6. A photograph of the entire map is contained in the Karpinski collection (for which see n. 69), but that photograph is so dark that a reproduction of it would not have been serviceable. Figure 5 reproduces a faithful tracing made by Ganong and printed in his "Crucial Maps" (IX), in *Proceedings* . . . , **31**, 1937, as fig. 122. Ganong, who discusses this map on pp. 127–130, remarks that the name *Coste de Cadie* "is the modern survival of the old Arcadia of Verrazano," but does not comment otherwise on the form *Cadie*.

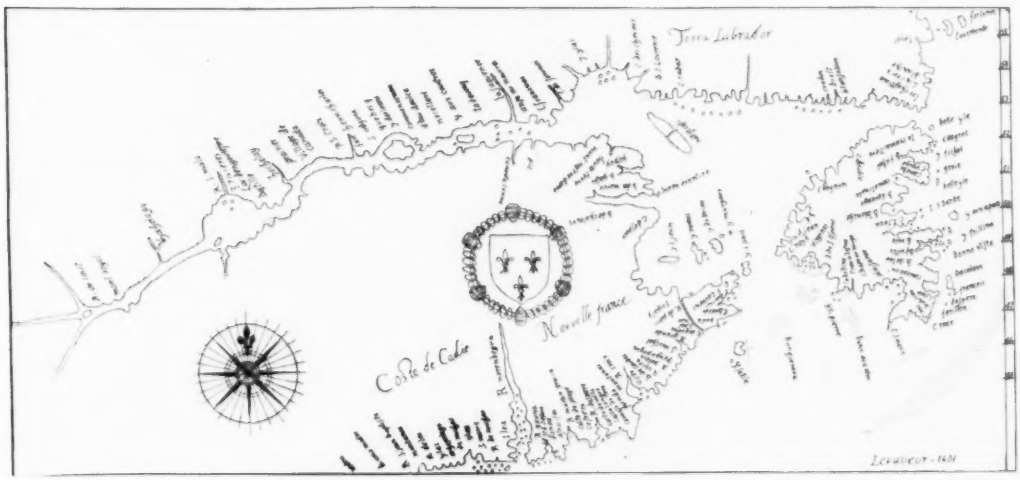

FIG. 5. Part of Levasseur's map of 1601.

map which Levasseur would have assimilated into his world-map the best that he could." Of the portion of the map below the names *Cadie* and *Nouuelle France* Ganong writes: "In great contrast, the mainland to the west . . . is wholly of the old Gomez-Ribero-Homem type. . . . Its topography, however, is accentuated in a detail that can be nothing other than imaginary." [41]

Of Levasseur himself Fournier has this to say:

> Cèt homme quoy que Tisseran en son bas aage, ayant eu quelque instruction d'un nommé Cossin, homme fort ingenieux, & qui auoit une excellente main, & veu les memoires de certains Prestres d'Argues, Bourg prés de Diepe, qui estoient excellents Geographes, dont l'vn se nommoit des Celiers, e l'autre Breton, a si bien sceu menager ce peu de lumiere qu'il a receu d'eux, qu'à force d'esprit et de trauail continu, il est arriué à tel point qu'il a esté admiré de plusieurs.[42]

XII. CHAMPLAIN'S *ARCADIE*

Chauvin, who had made a second voyage to New France in 1602, died early in 1603, probably early in February.[43] Immediately after his death a Commission as Lieutenant General was given to Aymar de Chastes, who wisely decided that further exploration should be undertaken before another attempt to establish a colony should be made. In the spring of 1603, accordingly, he arranged that Samuel de Champlain should be attached, as explorer, to a royally licensed fur-trading expedition. Soon after that expedition had sailed, de Chastes died.[44]

The expedition established its headquarters at Tadoussac. In July, Champlain visited the Gaspé peninsula, and while there he gathered much information as to the region to the south and east. Before or, less probably, soon after his return to France (in September) he wrote a full report of what he had seen and heard while in America. In the autumn he presented this report to Henry IV, and received a privilege to print dated 15 November. The report was promptly printed in Paris (with a second printing in 1604), under the title *Des Sauuages, ou, voyage de Samuel de Champlain, de Brouage, fait en la France nouuelle, l'an mil six cens trois.* The contents are summarized on the title page in three paragraphs, of which the third reads thus: "De la coste d'Arcadie, des terres que l'on y a descouuertes, & de plusieurs mines qui y sont, selon le rapport des Sauuages." Champlain's report of the information he had gathered while on the Gaspé peninsula appears in Chapter X, which contains this passage:

> Passant le destroit de l'isle de sainct Laurens [Cape Breton Island], costoyant la coste d'Arcadie, on vient dedans vne baye [the Bay of Fundy] qui vient ioindre ladicte mine de cuiure. Allant plus outre, on trouuve vne riuiere [St. John river] qui va quelques soixante ou quatre-vints lieues dedans les terres, laquelle va proche du lac [Lake Champlain] des Irocois, par où lesdicts Sauuages de la coste d'Arcadie leur vont faire la guerre.

The name *Arcadie* appears also in the heading and (four times) in the text of Chapter XII, in which Champlain summarizes a special report on Nova Scotian mines.[45]

While the first sentence quoted above refers obviously to the coast of Nova Scotia, Champlain's references, in the second sentence, to the St. John and to the *Sauuages de la coste d'Arcadie* as going far inland to make war show that he thought of the name as covering not Nova Scotia alone, but a larger region including Nova Scotia.

He may have derived his name *Arcadie* from Thevet, or from a lost map on which it appeared in that form, or—making his own French adaptation—from a map on which it appeared in the form *Arcadia*.

He undoubtedly submitted a map with his report to King Henry; but that map is not known to be extant.

XIII. THE SIEUR DE MONTS

Early in the autumn of 1603, and certainly before 31 October, the Sieur de Monts [46] submitted to King Henry a document proposing, in seven paragraphs, that he be authorized to undertake exploration and colonization in New France, that he be given the title and powers of Viceroy and Captain General, and that he be granted certain

[41] *Loc. cit.* in the previous note. The erroneous character of Levasseur's use of the Gomez names will be pointed out below, in n. 64.

[42] *Op. cit.*, 506.

[43] For references, see n. 39.

[44] Ramé, 23–25; Gosselin, 20–21; Bréard, 92–98; Biggar, 46–50; Allison, 37–38. No copy of De Chastes' Commission is known to exist: Dr. De Cesare has found none in the Registres du Parlement.

[45] *The works of Samuel de Champlain*, ed. by H. P. Biggar, 1: 166–172 and 180–185, Toronto, 1922. The French text of the *Des sauuages* is collated by J. H. Cameron. The *Des sauuages* is translated and edited by H. H. Langdon, from whose notes my bracketed identifications of Champlain's place names are taken.

[46] On whom see W. I. Morse, *Pierre du Gua, Sieur de Monts*, London, 1939.

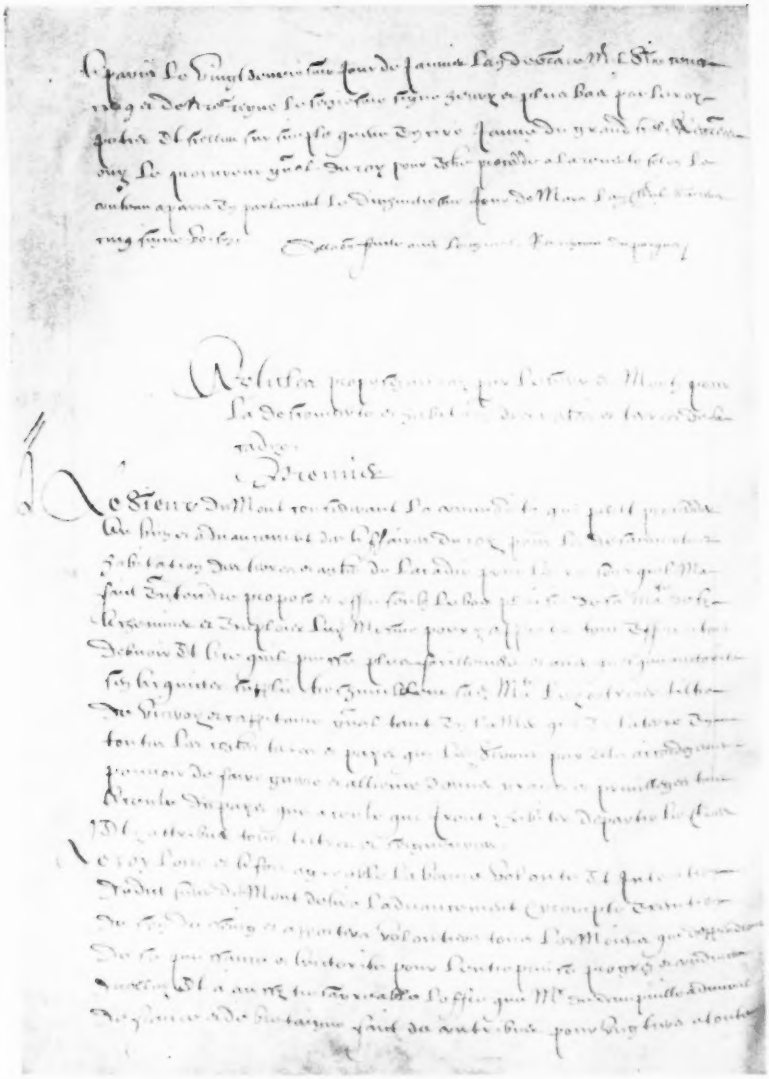

FIG. 6. The beginning of De Monts' proposal in the composite copy of 1605.

aids and privileges, among them a ten-year monopoly of the fur trade. This was the first document related to the first even temporarily successful attempt at colonization in New France, and the first document to contain any form of the name *Acadie*. The original document does not exist, nor was it ever copied, *as an independent document*, as far as we know. On 6 November 1603, however, there was drawn up at Fontainebleau a composite document in which each of the several paragraphs of De Monts' Proposal was followed by a paragraph signifying royal approval. The original of this composite document does not exist; but there does exist, in the Registres du Parlement, a manuscript copy of this document made on or shortly before 16 March 1605; the

first page of this copy is reproduced herewith as figure 6. In this copy the first of the seven paragraphs of De Monts' Proposal begins thus:

> Le Sieur deMont considerant la commodite qui peut procedder au bien et aduancement des affaires du roy pour la descouverte et habitation des terres et costes de lacadie. . . .

The second paragraph contains the phrase "toute lestendue des costes et contrees maritimes du dict pais de lacadie."[47] Unfortunately, the fact that the name of the region concerned appears as *lacadie* in the 1605 copy of the composite document does not suffice to enable us to determine whether that name appeared as *lacadie* or as *la cadie* in the original composite document of 6 November 1603, or in De Monts' original Proposal.

On 31 October 1603 the Conseil d'Etat gave its approval to De Monts' Proposal; and on or as of that same day Charles de Montmorancy, Admiral of France, issued to his subordinates a long order (in the course of which he refers to the action of the Council) designating De Monts as his Vice-Admiral for the region concerned. Neither the original nor any manuscript copy of this document is known to exist. It was printed, however, in Paris, in 1605, on pp. 12–18 of a booklet entitled *Commissions du Roy & de Monseigneur l'Admiral, au sieur de Monts, pour l'habitation és terres de Lacadie, Canada, & autres endroits en la nouuelle France. Ensemble les defenses premieres et secondes à tous autres, de trafiquer auec les Sauuages desdites terres. Auec la verification en la Cour de Parlement à Paris.*[48] In this document, as thus printed, the name of the region concerned appears five times, always in the form *Lacadie*. This fact does not enable us to determine whether that name appeared as *lacadie* or as *la cadie* in the original document of 31 October 1603. In the booklet as a whole the name appears twenty times, always in the form *Lacadie:* this, however, may well be the result of an arbitrary decision by the printer, since it is inherently unlikely—in view of the variations presently to be noted—that the name was spelled consistently in the manuscript material from which the printer worked.

This same document was printed again, in Paris, in 1609, by Marc Lescarbot, in his *Histoire de la Nouuelle France.*[49] In this print the name, on each of its five occurrences, appears in the form *la Cadie*. Lescarbot prints elsewhere certain documents that are not included in the booklet of *Commissions:* he was, therefore, not entirely dependent on that booklet for his material. His *la Cadie* may represent either use of a manuscript copy not used for that booklet, or an arbitrary decision to substitute *la Cadie* for the *Lacadie* of the booklet. He uses the form *la Cadie* consistently in all of the four documents concerning De Monts that he prints. Lescarbot was a man of letters, and had himself been in New France; but even this does not suffice to prove that he was accurate in printing *la Cadie* as the form used by Montmorancy.

On 6 November 1603, as has been said, there was drawn up at Fontainebleau a composite document in which each of the several paragraphs of De Monts' Proposal was followed by a paragraph signifying royal approval, and of this composite document a manuscript copy, made on or shortly before 16 March 1605, exists in the Registres du Parlement. In this copy the document is headed "Articles proposez au roy par lesieur deMonts pour la descouverte et habitation des costes et terres de lacadye" (the *la* stands at the end of a line: the copyist may or may not have thought of the *la* and the *cadye* as constituting a single word); and in the paragraph signifying approval of De Monts' third paragraph the name appears, without the definite article, in the phrase "en dict pays et contrees dacadie."

Henry's Commission to De Monts (as Lieu-

[47] The reference for this copy, as it exists in the Registres du Parlement, is X I A 8645 ff. 222v–223v. I have obtained photographs of it, and of the Commission to De Monts that is presently to be referred to; my quotations from these two documents are based upon these photographs. I have received relevant information, also, from the Direction des Archives de France (in a letter of 28 June 1955) and from Dr. De Cesare. The copyist, who was also the copyist of the Commission, makes no use of accents, apostrophes, or hyphens at line ends, and sometimes, though not usually, connects the definite article with its following noun. A printed form of this composite document appears in the *Collection de manuscrits contenant lettres, mémoires, et autres documents historiques relatifs à la Nouvelle-France,* pp. 40–43 (and thence in Morse, pp. 6–8), Quebec, 1883; but there are numerous matters of orthographic detail in which the text as there printed differs from the text of the manuscript copy as it exists in the Registres du Parlement.

[48] I have used the fascimile edition published in Bar Harbor in 1915, with an introductory note by G. B. Dorr. Morse, 4–6, reprints the document from this booklet.

[49] It appears on pp. 459–464 of the edition of 1609, and on pp. 492–494 of the edition of 1911.

tenant General, not as Viceroy), was issued two days later, on 8 November 1603. The original document does not exist, but there does exist, in the Registres du Parlement, a manuscript copy made on or shortly before 16 March 1605.[50] In this copy the name of the region concerned appears at four points: first as *lacadye*, then as *laccadie*, then as *la cadye*, and finally as *laccadie*. The Commission is printed both in the booklet of 1605, in which the name appears consistently as *Lacadie*, and in the *Histoire* of Lescarbot, in which it appears consistently as *la Cadie*.[51]

An early English translation of this Commission, preserved among the British State Papers,[52] is headed *The Patent of the ffrench Kinge to Monsieur De Monts for the inhabitinge of the countries La Cadia, Canada, and other places in New ffraunce;* shows the regional name, at each of the four points, in the form *La Cadia;* and is endorsed "The copie of the ffrench Kings Patent to Mounsieur de Monts of La Cadia Canada &c. granted 8 Noveb 1603, fro 40 to 46 degrees." [53] The source of this translation is not known; it may have been based on Lescarbot.

Fourteen other documents of the years 1603–1605 that bear on the appointment and activities of De Monts appear in modern prints.[54] In these documents, *as printed*, the name appears twelve times as *l'Acadie*, six times as *la Cadie*, twice each as *Lacadie* and as *Lacadye*, and once each as *l'Acadye* and as *Cadie* (without the definite article).

The conclusion properly to be drawn from all the material presented in the present Section is that in France in the years 1603–1605 the name of the region concerned was thought of sometimes as *Acadie*, and sometimes as *Cadie*, preceded usually, but not necessarily, in each case, by the definite article. Proof that the form *Acadie* thus existed is afforded neither by the early *Lacadie* nor by the modern printed *l'Acadie*, but by the fact that *acadie* occurs without the definite article in the document of 6 November 1603 and by the fact that the form *laccadie* occurs twice in the document of 8 November 1603. As far as we know, the *Cadie* of Levasseur's map of 1601 is earlier than any occurrence of *Acadie;* but it is possible, though not demonstrable, that the form *Acadie* had been used by or before 1601. A discussion of ways in which either *Acadie* or *Cadie* might have emerged from *Arcadie* will be found below, in Section XVI.

In De Monts' Proposal and in some of the related documents the 40th and 46th parallels are specified as the southern and northern boundaries of his domain (actually the 40th parallel runs through Philadelphia, and the 46th across Cape Breton Island). This fact and various items in the documents concerned show that the name *Acadie* or *Cadie* as it occurs in those documents was used with reference not to Nova Scotia only, but to a larger region including Nova Scotia.

XIV. CHAMPLAIN'S *ACCADIE*

When De Monts and his colonists set sail in the spring of 1604 Champlain went with them, as the official geographer of the expedition. In June the colony established itself on the Isle de Sainte Croix (Dochet Island) in Passamaquoddy Bay, between Maine and New Brunswick. This site having proved unsuitable, the colony moved, in the summer of 1605, to Port Royal (Annapolis Royal) in Nova Scotia. There it remained until the summer of 1607, when the settlement was abandoned, the surviving colonists returning to France. During these three years Champlain made three exploratory voyages to the west—the first taking him as far as Penobscot Bay, the other two taking him to Cape Cod. Throughout these years he kept a careful journal, which was published in Paris, in 1613, as Book I of a work entitled *Les voyages du Sieur de Champlain.*[55]

Within this Book the name that Champlain gives to the region of De Monts' lieutenancy is, in

[50] The reference is X I A 8645 ff. 224r–226r.

[51] *Commissions* . . . , pp. 3–12; Lescarbot, ed. of 1609, pp. 452–459; ed. of 1911, pp. 490–492.

[52] The reference is British State Papers, Colonial, **1** (for 1574–1621), No. 10. Calendared in *Calendar of State Papers, Colonial Series, 1574–1660*, ed. by W. N. Sainsbury, 4, London, 1860. Printed by Beamish Murdoch, *History of Nova Scotia* **1**: 21–24, Halifax, 1865; and by C. W. Baird, *History of Huguenot emigration to America* **1**: 344–347, New York, 1885; and thence in Maine Historical Society, *Documentary history of Maine* **7**: 2–6, 1901.

[53] Professor Robert Weiss has been so very kind as to examine the original document for me, in the Public Record Office. He reports that the form of the name is in fact *La Cadia;* that the translation was certainly made after the date of the original commission; that the endorsement quoted above is written in the same hand as the text; and that a second endorsement, "Acadia, Canada, &c. Novr. 1603," was written considerably later.

[54] *Collection*, 44–51; Morse, 8–20.

[55] Ed. and trans. by Ganong, in *The works of Samuel de Champlain*, vol. cit. The page references for Champlain's uses of the name *Accadie* are 236, 238, 293, and 338.

each of the four cases in which he uses such a name (in Chapters II, IV, and VII), *Accadie*. In each case it occurs in the phrase "coste d'Accadie." The context, in two of the four cases, is such as to indicate that he is using the name with reference not to Nova Scotia only, but to the region of De Monts' lieutenancy in general.[56]

XV. LESCARBOT'S *LA CADIE*

Marc Lescarbot, who was a member of the colony at Port Royal from the summer of 1606 to the summer of 1607, wrote in 1608, after his return to France, his *Histoire de la Nouuelle France*, which was published in Paris in 1609. He does not use any form of the name in question either in his own text or on his illustrative map, but he quotes in full, perhaps from the *Commissions du Roy & de Monseigneur l'Admiral*, four of the seven documents contained in that booklet, and in every case he uses the form *la Cadie*.[57]

XVI. *ARCADIE* BECOMES *ACADIE*

It has been shown in Sections VII–XV that on several maps that are certainly or probably of the third quarter of the sixteenth century the name *Larcadia* or *Arcadia* appears as a regional name below or to the right of a regional name meaning New France; that on a map published in 1585 the name *Arcadia* is applied specifically to Nova Scotia; that the name *Arcadie* was used by Thevet, in 1575, for the whole region; that during the second half of the century, and especially in its last two decades, French fishermen plied the waters of New France and French fur traders were active along the St. Lawrence and to some extent elsewhere in New France; that a map made by Levasseur in 1601 bears the regional name *Coste de Cadie* in association with, but to the left of, the name *Nouuelle France;* that in Champlain's *Des sauuages*, written in 1603 as a report upon his journey of that year, the whole region is referred to as *Arcadie;* that in early copies or printings of the Commission given to De Monts in the autumn of 1603, and of the two documents most immediately related thereto, the whole region is variously named as *lacadie, Lacadie, La Cadie, lacadye, acadie, laccadie*, and *la cadye;* that in modern printed forms of other later documents of the years 1603–1605 that are related to activities of De Monts the name appears in the forms *Lacadie, l'Acadie, Lacadye, l'Acadye, la Cadie*, and *Cadie;* that Champlain, who accompanied De Monts on his expedition of 1604–1607, used the form *Accadie* in the journal that he kept while on that expedition; that in 1608 Lescarbot, quoting some of the De Monts documents, used the form *la Cadie;* and that in an approximately contemporary English translation of De Monts' Commission the name appears as *La Cadia*.

That the various forms without the *r* are derived from the forms with the *r* there can be no doubt: the cartographic sequence, as represented by Levasseur's map of 1601 in relation to preceding maps, and the use of the form *Arcadie* in 1603 by the most experienced and competent geographer of the time, are conclusive. The fact of this derivation was first recognized and pointed out by Ganong.[58]

In view of the background as perceived in part by Ganong and as fully presented in the present study, it is indeed obvious that the forms without the *r* are continuants of the forms with the *r*—and that fact is all that really matters for the further purposes of this study. The explanation of the fact, however, is by no means obvious; and the following suggestions as to possible explanations seem, therefore, to be worth offering.[59]

It is to be borne in mind in this connection that the name *Arcadie*, though it had been used by Thevet and was used in 1603 by Champlain, was not a fixed and familiar name, but a name recently used for a region of which relatively few people—most of whom were fishermen or fur traders—had any knowledge: it was therefore a name readily subject to modification.

[56] The map that Champlain made to accompany this Book does not carry the name *Accadie* or any equivalent thereof. It is reproduced in his *Works*, ed. cit., Portfolio, pl. LXXX.

[57] On Lescarbot see H. P. Biggar's Introduction in *The history of New France by Marc Lescarbot*, ed. and trans. by W. L. Grant, 1, Toronto, 1907. The four documents appear on pp. 452–472 of the edition of 1609, and on pp. 490–498 of the edition of 1911.

[58] In the article cited in n. 35, in which Ganong refutes at great length and conclusively the older theory that the name *Acadie* was derived from a local Indian place-name suffix—*acadie;* and in the article cited in n. 27.

[59] In the second of the two articles referred to in the preceding note Ganong remarks: "From Champlain's *Arcadie* to the later *Acadie* the transition is perfect." This, however, simply begs the question, and shows a lack of adequate linguistic understanding. The initial syllable *Arc-* is by no means un-French: one thinks, for instance, of the place names Arcachon and Arcueil, and of such words as *arcade* and *arcane*.

The earliest extant appearance of a form of the name without the *r* is as *Cadie*, on Levasseur's map of 1601. By 1605, however, the form *Acadie* was also in use; and it may be that maps or documents now lost or unknown would have shown the form *Acadie* to have been in use in earlier years. There are then two possibilities: one, that the sequence of forms was *Arcadie—Cadie—Acadie;* the other, that the sequence of forms was *Arcadie—Acadie—Cadie*. Either sequence is explicable.

The fishermen and fur traders who went to New France in the late sixteenth century must have had coastal charts of some kind; these charts must have been based, to some extent, on such maps as were available; on some of those maps the name *Arcadia* (or perhaps *Arcadie*) must have appeared as a designation of the southern portion of New France; and some form of that name may well have appeared upon coastal charts used by fishermen and navigators, and may have entered into spoken use among them. These fishermen and fur traders were not interested in exact cartography or in exact nomenclature: their concern was merely practical. It would then be quite natural for them to use a simpler and abbreviated form, *Cadie*, in place of the more elaborate form, *Arcadie*.

It may also be noted that there are varieties of Breton speech in which the *r* is strongly guttural.[60] It would seem, therefore, that the name *Larcadie*, as pronounced by a Breton, might have been thought by a non-Breton to consist of two elements, *la* and *cadie*, separated by an indeterminate sound having the effect of a very rough breathing.[61]

If the form *Cadie* came into use, in any way, it would be perfectly natural for the French definite article *la* to become associated with it, as it is associated, in French, with so many other regional names; and if the form *La Cadie* came into use, in this or in any other way, it would be quite natural, also, that the resulting pronunciation *lacadie* should have been thought to represent the identically sounding *L'Acadie*—the form *Acadie* thus coming into existence as a separate word.[62] This seems to me to be the most probable explanation of the development of the forms without the *r*.

On the other hand, the form *Acadie* might have come directly from *Arcadie* (or the form *Lacadie* from *Larcadie*) either as a result of a temporary French phonetic tendency, or less probably, as a result of the peculiarity of Breton speech that has already been noted. There existed in France in the sixteenth century a tendency toward the dropping of *r* (in speech) in groups consisting of *r* plus a consonant, as attested by such rhymes as *farce—embrace; bourse—courrouce*, and *garde—escalade;* but a contrary tendency, due in part to the influence of Latin, had led by the end of the century to the reestablishment of the original groups.[63] It is quite possible, however, that the fashion of dropping the *r* may have lingered along the northern French coast after it had died out in Paris. In a familiar word the silence of the *r* in pronunciation would not have affected its spelling: but in the case of a word just coming into use it might have resulted in the omission of the *r* in spelling.

It is possible that the name *Larcadie* as pronounced by a Breton—with an *r* lacking its normal identity—might have seemed to a non-Breton to represent the form *Lacadie*.[64]

The form *Acadie*, preceded by the definite article, would have been pronounced as *lacadie:* it would be quite natural that this pronunciation should have been thought to represent the identically sounding *La Cadie*—the form *Cadie* thus coming into existence as a separate word.[65]

[60] François Falc'hun, *Le système consonantique du Breton*, 49–51, Rennes, 1951.

[61] I am indebted to the kindness of M. Alain Seznec for a helpful discussion of this matter.

[62] Such re-division has occurred in certain French words: *l'abajoue* and *l'accoursie* are re-divisions of *la bajoue* and *la coursie*, and *l'alumelle* is a modified re-division of *la lemelle*.

[63] See W. von Wartburg, *Evolution et structure de la langue française*, 3rd ed., 162–163, Bern, 1946. I am indebted to the kindness of Professor R. L. Politzer for a helpful discussion of this matter, and for the reference to Wartburg's book.

[64] A very different explanation of the origin of the form *Acadie* is at least possible. Many early maps abound in errors, and the loss of the *r* might be due ultimately to its omission in some now lost or unknown map or chart. In Levasseur's map, in which many names are taken from old Gomez names, the Spanish *verde* and *Buena madre* appear as *Vedra* and *buana madre;* the name *R. de los* is obviously incomplete; *arcipelago* becomes *arhepelago; C. de muchas ylas* is broken into two names, *de muchas* and *yles; R. de muchas* is obviously incomplete; *R. de las gamas* becomes *R. gaune;* and *medanos* and *arecifes* become *danos* and *asracifes*. The Spanish names in this note are taken from the table in Ganong, Crucial maps (IV), in *Proceedings* . . . **26**, Sect. II: 140–141, 1932.

[65] It may be noted that in later times, as will appear below, the substantives *Acadiens* and *Acadians* have been often replaced in certain localities by the forms *Cadiens, Cayens*, and *Cajuns*.

Whatever the explanation may be, the outcome of the process was most fortunate: for the name *Acadie* and its English equivalent *Acadia* are both excellent names, pleasant to utter and pleasant to hear, and perfectly distinctive.

XVII. 1610–1755: *ACADIE*

Throughout this period France (with Indian assistance) and England (with assistance from New England) were in intermittent conflict for the possession of the undefined larger region that included Nova Scotia. Until 1710 France was usually, but not always, in control. In 1710 control passed to England and thereafter remained with England, though that control was by no means complete or unchallenged.[66]

During this period the name *Acadie*, or a French variant thereof, appears, with or without the definite article, in French writings and on French or other Continental maps, applied sometimes to the larger region and sometimes specifically to Nova Scotia.

Champlain, after 1610, uses the form *Acadie*, applying it to the larger region.[67] Pierre Biard, a Jesuit missionary who was in Nova Scotia and thereabouts in the years 1611–1613, published in 1616 a *Relation de la Nouvelle France* in which he uses the form *Acadie*, applying it specifically to Nova Scotia.[68]

I have examined in the Harvard University Library 66 French or other Continental maps that are of this period and show the name *Acadie* or a French variant thereof.[69] The form *Acadie* appears on 49 of these maps, the form *Accadie* on twelve, the form *Cadie* on two, and the forms *Acadye* and *Lacadie* on one each, while one map has *Cadi* (in the phrase Côte de Cadi) in the western part of the region concerned, and *Acadi* for the peninsula.[70] The name is applied specifically to Nova Scotia in most cases, but in a few cases to the larger region.

During this period also, as the French and French-descended population of Nova Scotia grew from almost nothing to about ten thousand, the substantive *Acadiens* came into use.

XVIII. 1610–1755: ENGLISH USAGE

Reference has already been made to the appearance of the form *La Cadia* in the early English translation of the Commission issued to De Monts in 1603. If that translation was made from the form of the Commission printed by Lescarbot in 1609, as it may well have been, its actual date would be presumably about 1610.

In 1621 King James I granted to his Scottish courtier Sir William Alexander (later made Earl of Stirling) a Charter authorizing him to colonize the lands lying between Gaspé Bay and the St. Croix River, "quaequidem terrae praedictae omni tempore affuturo nomine Novae Scotiae in America gaudebunt." Sir William's attempts at colonization failed—but the name of his proposed colony has endured.[71] In royal documents issued thereafter, prior to the establishment of the Commonwealth, the region is referred to consistently as Nova Scotia or as New Scotland.[72]

There are, however, two documents of these same years in which a form of the name *Acadie* appears. The first is an "Information" submitted by Lord Ochiltree in 1630, perhaps in January,

[66] See A. G. Doughty, *The Acadian exiles*, Chap. I-VII, Toronto, 1916, and J. B. Brebner, *New England's outpost: Acadia before the conquest of Canada*, New York, 1927.

[67] See his *Works*, ed. cit., **3**: 331, 1929, and **6**: 307, 1936.

[68] See R. G. Thwaites, *The Jesuit relations and allied documents* **3**: 40, 44, 60, 262, and 266, Cleveland, 1897. For other French writings containing the name see an anonymous eighteenth-century *Memoire touschant les pretentions des François et des Anglais sur les terres de la Nouvelle France*, in the *Collection de manuscrits* . . . **1**: 9–24.

[69] Of these maps, 36 are originals; 21 are reproductions contained in the L. C. Karpinski collection of "Manuscript maps, prior to 1800, relating to America; photographic facsimiles made from originals in various libraries and archives in Paris, Spain, and Portugal"; five are reproductions contained in the *Cartografia de Ultramar*, Portfolio II (for the United States and Canada), Madrid, 1953; and the other four are reproductions found elsewhere.

[70] The maps showing the form *Cadie* were made in 1640 and 1653 by Jean Janson. The map showing both *Cadi* and *Acadi* is numbered S.H.A. 132-2-3 in the Archives of the Service Hydrographique de la Marine. A photographic facsimile of the western part of it is contained in the Karpinski collection. Dr. De Cesare, who has examined the map itself for me, reports that it was probably made about 1700; that the name of its maker is not known; and that it has never been published.

[71] See Brebner, 21–27. The Charter is printed in *Royal letters, charters, and tracts, relating to the colonization of New Scotland, and the institution of the Order of Knights Baronets of Nova Scotia*, ed. by David Laing, 3–15 (in the separate numbering for the series of Charters following the long Preface), Edinburgh, 1876. The quotation is from p. 5. Sir William is still remembered as a writer of Petrarchistic verse.

[72] *Royal letters* . . . , Preface, *passim*.

in which the name appears as *Lacady*.[73] The second is a letter written on 30 March 1632 by Sir Isaac Wake, the English ambassador to France: in this letter, addressed to English officials in Port Royal, Sir Isaac states that he has completed negotiations "particularly concerning Cadie & Noua Francia," and directs his addressees to be ready, on the arrival of Monsieur Rasilly, or his representative, "to void & quitt the ffort & habitation of Port Royal in Cadie." [74]

Cromwell seems to have used the forms *Acadie* or *Acadia* or variants thereof. Sainsbury uses the form *Acadia* in his summary of a document of 14 July 1656 and the form *Laccady* in his summary of a document of 9 August 1656.[75] On 17 September 1656 Cromwell issued a commission to Colonel Thomas Temple, a copy of which, made from the original document, was officially recorded in Boston on 6 July 1657: in this copy the name appears in the phrase "the Countrjes and territorjes called Lacadye otherwise Accadja." [76] On 26 September 1656 Cromwell addressed a letter of instruction "to Cap[n] John Leveret Governour in chief of our Forts of St. John Port Royall, and Pentacoet in Acadia commonly called Nova Scotia in America." The name appears in the form *Acadia*, also, in the body of the letter.[77]

In other English writings usage varies. The forms *La Cadia* and *L'Cadia* occur in a document of March 1660.[78] In John Ogilby's *America* (London, 1671), Book II, Chapter I, one of the sections is entitled "Accadia, or Nova Scotia." In the course of the chapter Ogilby uses now *Accadia* and now *Accadie*. The adjective *Accadian* appears in the sentence "Poutrincourt . . . endeavoring to Plant Christianity among the Natives, Christen'd among others an Accadian Lord, who was above a hundred years old."

I have examined in the Harvard University Library six maps of this period on which the nomenclature is English, and on which the name *Acadia* or a variant thereof appears. The earliest of these maps, an unsigned map made about 1700, shows the name in the form *Acadia*, as do all the others, except a map made in 1749 by Morris, which bears an inscription reading: "This country from Kenneback River to Cape Rozier was always called by the French Accada," and another inscription (at a point on the St. John River) reading: "Here inhabit about 20 families of Accadians." On four of these maps the name is applied to the larger region; on two it is applied to Nova Scotia.[79]

XIX. 1610–1755: LATIN USAGE

The earliest passages known to me in which *Acadia* is used as a Latin noun occur in the Latin text of the Treaty of Breda of 1667, in Sections X and XI of that portion of the treaty that cover relations between England and France. Section X begins thus:

> Dictus etiam Dominus Magnae Britanniae Rex, dicto Domino Regi Christianissimo. . . . Regionem quae Acadia dicitur in America Septentrionali sitam, qua dictus Dominus Rex Christianissimus olim potiebatur, restituat.

Section XI begins thus:

> Si qui vero ex incolis regionis illius quae Acadia dicitur, Serenissimi Magnae Britanniae Regis dominio imposterum subesse malint, liberum sit ipsis intra spatium unius anni . . . discedere. . . .[80]

The reference in this case is to the larger region.

I have examined in the Harvard University Library eight maps of this period on which the

[73] The reference is British State Papers, Colonial, **5** (for 1629–1630), No. 47. Printed in *Royal letters . . .*, Preface, pp. 54–55. Calendared by Sainsbury on p. 106 of the vol. cit. in n. 52. In the *Royal letters . . .* the name is printed as *Acady*, and Sainsbury, in his summary, uses the form *Acadia* (not in quotes). It is to the kindness of Professor Weiss, who has examined the original document for me, that I owe the certainty that the form of the name as it actually appears therein is *Lacady*.

[74] The reference is British State Papers, Colonial, **6** (for 1631–1633), No. 56. Calendared by Sainsbury on p. 152. My quotations are taken from a photograph of the original letter, furnished by the Public Record Office.

[75] Vol. cit., pp. 444 and 447.

[76] The Boston copy is printed in *Suffolk deeds* **3**: 22–26, Boston, 1885, and in the *Collections of the Maine Historical Society*, Ser. II, **5**: 282–287, Portland, 1901.

[77] Printed in the *Collections of the Massachusetts Historical Society*, Ser. IV, **2**: 233, Boston, 1854. Sainsbury in summarizing other documents of 1655 and 1656 uses the form *Acadia*—but not in quotes: vol. cit., pp. 423, 441, and 453.

[78] *Royal letters . . .*, Preface, pp. 116–117.

[79] Four of these six maps, by Kitchin, Mitchell, and Moll (2) are originals. The other two, one unsigned and the other by Morris, are photographic reproductions contained in A. B. Hulbert's *The Crown collection of photographs of American maps*, **4**, Nos. 7 and 9–10, Cleveland, 1928.

[80] Quoted from *Articuli Pacis & Confoederationis inter Serenissiumum & Potentissimum Principem Carolum II . . . et Serenissimum ac Potentissimum Principem Ludovicum XIV . . . Conclusi 21/31 die Mensis Julii, Anno Dom. 1667*, London, 1667.

regional nomenclature is Latin and includes the name *Acadia* or *Accadia*. The earliest of these maps, made about 1690 by Visscher, shows the name in the form *Accadia;* the other seven show it in the form *Acadia*. On Visscher's map and on one by Gottlieb the name is applied to the larger region: on the other six it is applied specifically to Nova Scotia.[81]

XX. ACADIANS IN EXILE

After 1710, as has been said, the English retained control of Acadia; but relations between the English governors and the French population were always troubled. The Acadians were in general a quiet, peaceable, and industrious people; but there were those among them, and certain non-Acadians who had influence among them, who were irreconcilably pro-French and anti-English. Matters came to a head in 1755, when war between England and France was threatening; and the English governor, Charles Lawrence, took the drastic and brutal step of deporting the Acadian population as completely as he could: some six thousand persons were shipped to various American colonies—Massachusetts, Connecticut, New York, Pennsylvania, Maryland, Virginia, the Carolinas, and Georgia.[82]

Between 1758 and 1785 many of the exiles made their way to Louisiana, and there they settled, mainly, at first, in a region on the left bank of the Mississippi, about sixty miles above New Orleans, and later in other regions in southern Louisiana. The region of their first settlement was called *Côte d'Acadie;* and after Louisiana had been purchased by the United States, in 1803, this region became Acadia County. There is reproduced herewith, as figure 7, from an original in the Harvard University Library, part of a map made by Lafon in 1805, which shows the county as *Comté d'Acadie*, and shows within it a river named *R. des Acadiens*. In a later reorganization counties were replaced by "parishes"; the

[81] All eight maps are originals. The six made by men not named in the text are by Allard, Homann, Seutter (2), Vander Aa, and Zurner.

[82] Doughty, Chapters VIII-X.

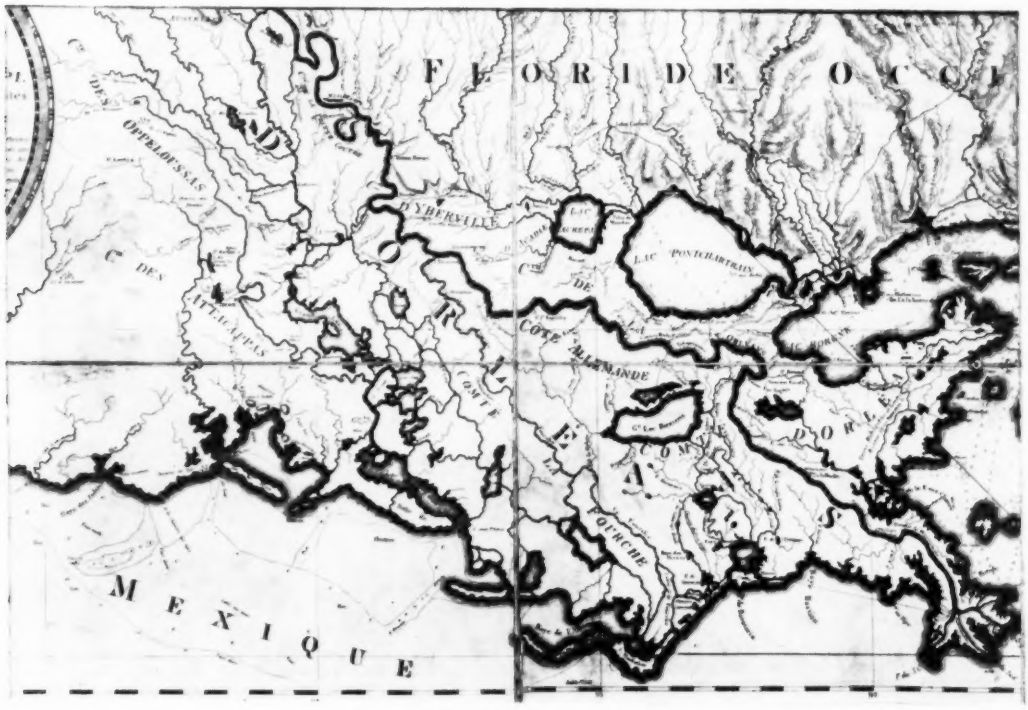

FIG. 7. Part of Lafon's map of 1805.

region that had been called Acadia County was divided into Ascension and St. James Parishes, and the name *Acadia* was given to a parish a hundred miles to the west.

The descendants of the Acadian settlers have multiplied and prospered, and have become a valued element in the life of Louisiana. They are often referred to as *Cadiens* or *Cayens* or *Cajuns;* and their colloquial speech is called *Cadien* or *Cayen.*[83]

XXI. RETURN FROM EXILE

A great many of the exiles who did not go to Louisiana resolved and endeavored to return to their homeland, and many succeeded, sooner or later, in making the long pilgrimage. After the signing of the Treaty of Paris in 1763 conflict in America between England and France came to an end, and the returning exiles were able to settle in the region from which they had been driven, or in other northern regions: there also they have multiplied and prospered.[84]

Names derived from *Acadie* persist in two settlements made late in the eighteenth century. About 1768 a number of Acadians settled about fifteen miles southeast of Montreal, in what is now St. John's County. They called their settlement La Cadie, or La Nouvelle-Cadie, or La Petite-Cadie. Later, as a parish, it was called L'Acadie, and eventually Sainte-Marguerite de Blairfindie: as a village it is now called L'Acadie. An adjoining parish, officially called Saint-Luc, is sometimes called La Petite-Acadie.[85]

At the time of the American Revolution a few hundred Acadians were living in the lower valley of the St. John; during and after the Revolution large numbers of American loyalists left the rebelling colonies and made their way into that same valley; and the pressure of this immigration forced the Acadians farther north, into the region called Madawaska, which comprises territory both in what is now Canada and in what is now Aroostook County, the northernmost county of Maine. In this region their descendants are still known as Acadians.[86]

XXII. ARCADIA IN VIRGINIA

Sir Philip Sidney's pastoral-heroical *Arcadia,* written about 1580, derives its title and some of its pastoral elements from the *Arcadia* of Sannazzaro. Early in its first book the charms of the Kingdom of Arcadia are thus set forth:

> There were hils which garnished their proud heights with stately trees: humble vallies, whose base estate seemed comforted with the refreshing of silver rivers: medows, enamelled with all sorts of eie-pleasing flowers: thickets, which beeing lined with most pleasant shade were witnessed so too, by the cheerful disposition of many well-tuned birds. . . .[87]

First published in 1590 (Sidney had died in 1586), the *Arcadia* won an immediate and long-enduring popularity. Editions appeared in 1593, 1598, 1599, 1605 (two editions), 1607, 1613, 1621, 1622, 1623, 1624, 1627, 1629, 1633, 1638, 1654, 1655, 1662, and occasionally thereafter.[88] Mona Wilson calls the *Arcadia* "the most successful book of the whole European age," and continues:

> Its vogue recalls the popularity of Erasmus's *Colloquies* and anticipates that of *Robinson Crusoe.* Until the invasion of French romances it held its own because no rival appeared. It drew housewives from their duties, and set a standard for the behaviour of their children.[89]

Settlement of the Accomack Peninsula began about 1620 near the southern end of the peninsula, and spread gradually northward.[90]

One of the earliest settlers was Captain Edmund Scarburgh, who had been educated at Caius College, Cambridge, came from England about 1620, and died about 1635. His son, also named Edmund, born in 1618, who had been left in England for his schooling, came to Virginia not long after his father's death. By the middle of the century he was the most prominent and the most powerful man on the peninsula. He was known as Colonel Scarburgh. He had lived originally in the southern part of the peninsula, but on 29 September

[83] S. A. Marchand, *Acadian exiles in the golden coast of Louisiana,* Donaldsonville, 1943; Emile Lauvrière, *Brève histoire tragique du peuple acadien,* 92–94 and 148–151, Paris, 1947; and Corinne L. Saucier, A historical sketch of the Acadians, in *Louisiana Hist. Quart.* **34**: 63–89, 1951.

[84] Doughty, 157–160; Lauvrière, 113–153.

[85] S. A. Moreau, *Histoire de l'Acadie, province de Quebec,* Montreal, 1908.

[86] C. W. Collins, *The Acadians of Madawaska* (= *New England Catholic Historical Society Publications, No. 3*), Boston, 1902.

[87] Quoted from the edition of 1655.

[88] S. A. Tannenbaum, *Sir Philip Sidney* (*a concise bibliography*), 2–3, New York, 1941.

[89] *Sir Philip Sidney,* 142, London, 1950.

[90] See R. T. Whitelaw, *Virginia's eastern shore, passim,* Richmond, 1951; and for Colonel Scarburgh, Mrs. Toft, and Arcadia Toft see Whitelaw's Index, s.vv. Alicado, Arcadia, Arcadia Creek, Arcadia Neck, Scarburgh (Edmund), and Toft (Anne, Arcadia, and Attalanta).

1663 he received a patent for a tract of some 1500 acres in the northern part, a tract that seems not to have been settled previously, and to have been at about what was then the northern limit of settlement. The tract is defined thus in his patent:

> Being a neck of land at the seaboard side, formerly elected by Richard Burdock & by him againe Declined called Arcadia Neck, bounded on the N. by a Cr. & br. called by the Indians Amburrocomico, now Gargaphe, on the S. by Arcadia Cr. &c.[91]

On 23 February 1664 a Mrs. Anne Toft, who had come from England in or about 1660, when she was seventeen years of age, received a patent for a tract of 1200 acres just north of Colonel Scarburgh's tract. Her tract is defined thus in her patent:

> At the seaboard side, to the Swd. of a Cr. called by the Indians Amburcomico, now Gargaphie, N. along the main br. of Kisquotan Cr. to the head of the main br. of same called Kirquotancke, now Arathusa, & Wly. to the head of Gargaphie Br.[92]

About 1663—perhaps a little earlier, perhaps a little later—there was born to Mrs. Toft a daughter whom she named *Arcadia*, for whom Colonel Scarburgh stood as godfather. Presumably the little girl was so named because of the name that had been given to her godfather's estate.[93] Mrs. Toft's second daughter, the date of whose birth is not known, was named *Attalanta*.

In view of the tremendous vogue of Sidney's *Arcadia* in the very years in which Colonel Scarburgh had had his English schooling it is clear that his use of the name *Arcadia* must have been occasioned by his knowledge of that novel. His liking for the name may well have been increased by direct knowledge of the *Eclogues* of Virgil. The names *Gargaphe* (or *Gargaphie*), *Arathusa*, and *Attalanta* are also of classic origin. All three occur in Ovid's *Metamorphoses; Arethusa* occurs in Virgil's *Eclogues;* and Atalanta occurs early in the first book of Sidney's *Arcadia*.

The name *Arcadia* is no longer current on the Eastern Shore. Arcadia Neck is now called White's Neck; and Arcadia Creek is now called Bundick's Creek.[94]

It is a most extraordinary coincidence that the name *Arcadia* given by Verrazzano in 1524 to the portion of the Accomack peninsula on which he had landed should have been given independently, a century and a half later, to a tract of land in the very same region.

Augustus Heermans, an energetic, adventurous, and ambitious surveyor and draughtsman of Bohemian birth, rose in New Amsterdam to become a prosperous merchant and a leading member of the governor's council. In 1659 he was sent on an official mission to Maryland; he was much attracted by the country there; and in 1660 he wrote to Lord Baltimore (who was then making grants of land and giving hereditary titles), offering

> to make an Exact mapp of the country if his Lordship would Please to Grant unto him the aboves.[a] Lands for an Inheritance to his Posterity and the Previledge of a Mannor.

Lord Baltimore promptly accepted the offer, assigning him some five thousand acres, chiefly in what is now Cecil County; in 1661 Heermans took up his residence there, naming his manor Bohemia Manor. In 1666 he was naturalized, being apparently the first person who received naturalization in any of the North American Colonies.[95]

He took the greatest of care in the preparation of his map, for which many surveys had to be made. His finished drawing was sent in 1670 to Lord Baltimore, then in England, and was enthusiastically received and acknowledged. A pas-

[91] Nell M. Nugent, *Cavaliers and pioneers: abstracts of Virginia land patents and grants, 1623–1800*, 425, Richmond, 1934. The "Cr." stands for "creek" and the "br." for "branch."

[92] *Ibid.* The patent is actually dated "23 Feb. 1663": Whitelaw (pp. 1141 and 1150) is presumably correct in taking 1663 to be Old Style for 1664.

[93] Whitelaw thinks it presumable that the estate was named in honor of the little girl.

[94] Whitelaw states that the Creek was referred to early in the nineteenth century as Alligator Creek, and later as Alicado Creek, and suggests that these two names may be corruptions of Arcadia Creek. This seems to me very improbable, though Alicado may have been a corruption of Alligator. The name Gargaphe (or Gargaphie) is perpetuated in the names of the village of Gargatha and of Gargathy Beach; see Whitelaw's Index, under headings beginning Garg-.

[95] On Heermans (whose name is spelled in several different ways) and on his map see J. G. Wilson, *A Maryland manor* (= the Maryland Historical Society, Fund-Publication No. 30, II), Baltimore, 1890, and Augustine Herrman, Bohemian, 1605–1686, in The New Jersey Historical Society, *Proc.*, 2d Ser., **11**: 23–34, 1890–1891; P. L. Phillips, *The rare map of Virginia and Maryland by Augustine Herrman, First Lord of Bohemia Manor, Maryland*, Washington, 1911; Covington, art. cit. in n. 7, pp. 207–209 and 215–216; *Dictionary of American Biography*, s.v. "Herrman, Augustine"; and Whitelaw (see his Index). The *Memorandum* from which the quotations are taken is printed by Wilson as an Appendix to his *A Maryland manor.*

FIG. 8. Part of Heermans' map of 1670.

sage in the *Memorandum or Journal of the first foundation and seating of Bohemia Mannor and Bohemia River Middle neck Adjacent & Appendant* reads thus:

Augustine Herman haveing his Mapp finished upon his own Cost and Charge no less than to the value of about 200 pounds Sterling besides his own Labour and Sent into England . . . his Lordship Replyed by Lett^r. Sep^r. 3^rd & Nov^r. 12^th: That his Lordship had Received no small Satisfaction by the Rarity of that Mapp and that the Kings Majasty his Roy^l Highness and all others Commended the Exactness of the work. Aplauding it to be the best mapp, that was Ever Drawn of any Country whatsoever. . . .

The map was engraved by William Faithorne, and published in 1673 in four sheets, one of which, showing the Accomack peninsula, is reproduced herewith as figure 8.[96]

Heermans and Colonel Scarburgh, men of great prominence and great activity living not far apart, must have known each other, and it is inherently probable that Heermans' studies for his map took him to the Colonel's *Arcadia*. In any case, the name *Arcadia* appears at the appropriate point on Heermans' map, covering, however, a territory much larger than Colonel Scarburgh's estate could have been.[97]

[96] From the reproduction published with Phillips' *The rare map. . . .* A facsimile edition of this map was published by the John Carter Brown Library (Providence, R. I.) in 1941.

[97] There is also an entry for "Scharburghs Gargaphia." The name *Arcadia* does not appear on any one of the

Heermans' map was very closely imitated by John Thornton in a map entitled "A Mapp of Virginia Mary-Land, New Jarsey, New York & New England," made within the period 1674–1682, and published in London.[98] The name *Arcadia* appears in the same position as on Heermans' map.

The name *Arcadia*, or a mistaken variant thereof, appears also, in the same position, on five later maps, all derived directly or indirectly from that of Heermans: maps of 1696 by Sanson, of 1725 by Homann (*Arcadra*), of 1729 by Moll (*Arcadi*), of 1740 by the Homann Heirs (*Arcadi*), and of about 1740 by Bowen.

XXIII. ARCADIA IN CALIFORNIA[99]

Lope de Vega's pastoral novel, *Arcadia*, written about 1590 and first published in 1598, derives its title and its general character from the *Arcadia* of Sannazzaro. It was immensely popular, at least eighteen editions appearing within the period 1598–1675.[100]

José Bandini, born in Andalusia in 1771, came to South America in 1793 and settled in Lima. Shortly after 1822 he came to California and settled in San Diego. With him he brought his son Juan, who had been born in Lima in 1800, and became one of the most prominent Californians of his time. José María Estudillo, born in Spain, probably in Andalusia, in 1772, came to California in 1795. Juan Bandini married Dolores, one of the daughters of José Estudillo. They named their first daughter Arcadia. She and her younger sisters were famous for their beauty. She married, first, Abel Stearns, a wealthy Californian, who in her honor gave the name Arcadia to a business block that he built in Los Angeles in 1858. After his death in the 1870's she married Robert S. Baker: she was then known as Doña Arcadia de Baker.[101]

No information as to the reason why Juan and Dolores Bandini gave the name Arcadia to their daughter has been preserved. It seems improbable, however, that they should have given her this name merely on the basis of the general classical tradition, and quite possible that they should have given it to her either as a result of fondness for Lope's *Arcadia* or as a result of a traditional use of the name due ultimately to the popularity of Lope's novel.

The city of Arcadia, not far from Los Angeles, was plotted and named about 1888 by Herman A. Unruh. The reason why he so named it is not known. Gudde attributes the choice of the name to the general classical tradition. Hanna suggests that it may have been named in honor of Doña Arcadia de Baker.

XXIV. *ACADIE* AND *ACADIA* IN AMERICA TODAY

There are today in Nova Scotia and elsewhere in Canada upwards of two hundred thousand persons of Acadian descent.[102] To many of them their homeland is still *Acadie* or *Acadia*. In Nova Scotia the name *Acadia* itself remains in the place name Acadia Mines—in the very region as to which Champlain received a report in 1603; in the name of Acadia University in Wolfville;[103] and doubtless in the names of various organizations. There is an Acadian Museum in Grand Pré. Reference has already been made (in Section XXI) to the village of L'Acadie and to the adjoining parish sometimes called La Petite-Acadie in St. John's County, Quebec. Far to the west, in the province of Alberta, a village bears the name of Acadia Valley.

An organization called "United States Acadians" is especially strong in Maine, Massachusetts, and Louisiana. Reference has already been made (in Section XXI) to the Acadians of Madawaska. On Mount Desert Island (which was so named by Champlain) the great reserva-

six earlier maps of this region known to me: John Smith's map of 1608; maps by Blaew and by Hondius, and the map that illustrates *A relation of Maryland, together with a map of the countrey*, all of 1635; a map by Schenk and Valk of about 1645; and Dudley's map of 1647.

[98] Reproduced in Stokes, 2: pl. 56, and discussed on p. 158.

[99] The name California is itself derived from a Renaissance novel, the Spanish *Las sergas de Esplandian*, in which a mythical country is so named: this novel, probably the work of Garci Rodriguez de Montaldo, was written before 1504 as a continuation of *Amadis de Gaula*. See Ruth Putnam, California: the name, in *Univ. of Calif. Publ. in History* 4 (4): 293–365, 1917.

[100] *Catálogo de la exposición bibliográfica de Lope de Vega*, 179–181, Madrid, 1935.

[101] H. H. Bancroft, *History of California* 2: 541–542 and 709–710, San Francisco, 1885; E. G. Gudde, *California place names*, 13, Berkeley, 1949; and P. T. Hanna, *The Dictionary of California land names*, 15, Los Angeles, 1951. I owe the two latter references to the kindness of Mr. J. deT. Abajian, Director of the California Historical Society.

[102] Doughty, 159–161.

[103] Founded in 1838 as Queen's College; its name was changed in 1841 to Acadia College and in 1891 to Acadia University.

tion which was officially created in 1916 as the Sieur de Monts National Monument and made a National Park in 1918, under the name Lafayette National Park, was renamed Acadia National Park in 1928.[104] In Boston and in New York, and doubtless in other cities, *Acadia* occurs as the first element of certain trade names. Reference has already been made (in Section XX) to survivals of the name *Acadie* in Louisiana.

XXV. *ARCADIA* IN AMERICA TODAY

The name *Arcadia* in its original form is borne today by the city of Arcadia in California, as noted above, by the city of Arcadia in Florida, and by townships, towns, villages, or rural areas in the States of Alabama, Arkansas, Illinois, Indiana, Iowa, Kansas, Louisiana, Michigan, Missouri, Nebraska, Ohio, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Utah, Virginia, and Wisconsin.[105]

The exact or approximate dates of the naming of these places (in a few cases even the approximate dates are not known) range from 1846 (Tennessee) to 1908 (Utah); nine—those in Illinois, Indiana, Kansas, Missouri, Ohio, Tennessee, and Wisconsin, and two of those in Michigan—were so named before 1862.

The few cases in which there is some record or tradition as to the reason for the choice of the name are as follows.

Iowa: "Old neighbors say that he [the founder] was struck with the beauty of the location."

Missouri: "Named for a Greek grazing country, which has furnished the word 'Arcadian' for the poets."

Nebraska: "She [the founder] understood the meaning of 'Arcadia' to be 'the feast of flowers.' At that time the valley was filled with beautiful wild roses in bloom, which made the name seem appropriate to her."

Oregon: "Named for the pastoral area of Greece . . . the promoters selected the name Arcadia in the expectation that life on the project would be ideal."

South Carolina: "So named because the surrounding scenery suggested the classical Arcadia."

Tennessee: named by Thomas Fain, "because the place was so serene and peaceful, lying in the beautiful Reedy Creek Valley between ridges."

Texas: "Named for Arcadia, Louisiana."

Utah: "So called because of its isolation and the high bluffs surrounding the town."

Wisconsin: "Suggested . . . for the real and fancied resemblance of the valley to the state of Arcadia in ancient Greece, the inhabitants of which enjoyed a peaceful and happy life."

The state in which the name has had the most remarkable fortune is Michigan. In 1830 a township named Arcadia was organized in Kalamazoo County; in 1835, however, its name was changed to Kalamazoo. In 1855 a township named Arcada was organized in Gratiol County, and in 1856 a township named Arcadia, also spelled Arcada, was organized in Lapeer County. In 1870 a township named Arcadia was organized in Manistee County, and a village of the same name was established there in the same year. At some time prior to 1899 a village named Arcadia Mine was established in Houghton County; in 1904, however, its name was changed to Franklin Mine. In 1899 a village named Arcadia Mine was established in Keweenaw County.

The story of the founding of the Kansan Arcadia is told thus in the *Arcadia Reporter* of 28 December 1878:

> Among those who first set foot in this part of the valley we might mention Philip Hathaway . . . and others. They conceived the idea of starting a town and establishing civilization, which movement was readily perfected and agreed upon. They met in a little log store room one night as if in secret conclave, and there different suggestions were made as to what name they should give the great Eureka they had found. It was finally agreed upon to call it "Arcadia" . . . [no reason is given] and it was sanctioned by all present. These old settlers or pioneers as you may term them felt proud and rolled up their sleeves to commence the building of a great city.

It may be noted that none of the states in which the name appears are among the original English colonies (with the exception of South Carolina, in which the village of Arcadia was so named only in 1902). The multiple use of the name seems to be an American phenomenon, largely or entirely independent of English influence. The period in which the earlier American Arcadias were so named was one in which the classics enjoyed a considerable vogue; presumably the choice of the name, at least in the earliest cases, was due

[104] G. B. Dorr, *Acadia National Park*, Bangor, 1942.

[105] My information with regard to the founding and the naming of these cities and villages has been obtained almost entirely through correspondence with officers of the Historical Societies of the several states concerned —many of whom, in their answers, have quoted local publications that are not accessible to me. I am very grateful for their cooperation, and for that of certain postmasters and other correspondents.

to a more or less definite memory of the *Eclogues* of Virgil. Those poems do not represent Arcadia as a place notable for its beauty, but they do represent it as being an attractive place; the modification of the tradition was perhaps due to the development of modern sensitiveness to landscape beauty.

The name *Arcadia* has found various other uses in the United States—as the name, for instance, of a bird refuge in Massachusetts, of a ballroom on Broadway, of a student governing body in a university in Pennsylvania, and of a country club in Missouri. In Boston and in New York, and doubtless in other cities, the noun *Arcadia* and the adjective *Arcadian* occur as the first elements of certain trade names.

In Nova Scotia—the original *Acadia*—the name *Arcadia* (with the *r*) was given on 27 January 1863 to a village previously called Upper Chebogue. The name *Arcadia* was chosen because a brig named *Arcadia* had been built there by Bartlett Gardner in 1817.[106]

As far as I am aware, the only place in South America that bears the name *Arcadia* is in Argentina, in the Province of Tucumán. The Argentine Arcadia, which is in the Department of Chicligasta, is a beautiful place, near the mountains, and near the city of Concepción. It takes its name from an old ranch, located there, which was owned by General Alejandro Heredia, governor of the Province of Tucumán from 1832 to 1838 (when he was assassinated). General Heredia, who held the doctorate *in utroque jure* from the University of Córdoba (Argentina), was a great reader, and very fond of the Greek and Latin classics. It was undoubtedly this fondness that made him familiar with the classic Arcadian tradition and led him to give the name of *Arcadia* to his ranch.[107]

XXVI. SUMMARY

All of the various forms of the name *Arcadia* that have been reported in Sections III–XXII of the present study—*Arcadia, l'Arcadia, Larcadia, Archadia, Arcadra, Arcadi, Cadie, la Cadie, Cadi, Lacadie, Acadie, l'Acadie, l'Acadye, Lacadye, Accadie, Acadi, La Cadia, L'Cadia, Acady, Laccady, Acadia, Accadia,* and *Accada*—as well as the adjectives *Acadien, Acadian, Accadian, Cadien, Cayen,* and *Cajun,* which are often used as substantives —are thus derived from the name of Sannazzaro's novel; and all of them come from Sannazzaro through Verrazzano and Gastaldi, except that *Arcadra* and *Arcadi,* and *Arcadia* as used on the Eastern Shore of Virginia and on maps based on that usage, come from Sannazzaro through Sir Philip Sidney.

It is possible that use of the name *Arcadia* in California may have come from Sannazzaro through Lope de Vega.

The name *Arcadia* as used in other states, in Nova Scotia, and in Argentina is presumably derived from a tradition that was itself based on the *Eclogues* of Virgil.

[106] I owe this information to the kindness of C. B. Fergusson, Assistant Archivist in the Public Archives of Nova Scotia.

[107] I owe this information to the great kindness of Professor Manuel Lizondo Borda of the University of Tucumán, author of the *Historia de Tucumán.*

SCIENTIFIC INSTITUTIONS SINCE THE RENAISSANCE: THEIR ROLE IN MEDICAL RESEARCH

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THIS study has stemmed from an inquiry into the origin of the modern independent medical research institute, and more specifically from an attempt to determine what institutes comparable in organization and purpose to the Rockefeller Institute for Medical Research existed prior to its foundation in 1901. Certain institutions had obvious affinities: for example, the Pasteur Institute in Paris and the Koch Institute in Berlin. Yet it soon became apparent that one could not understand the role of these establishments—any more than one could evaluate the position of the Rockefeller Institute—without placing them in their historical setting. To discover their significance as institutional forms it was necessary to relate them to other institutions with broadly similar aims but differing in structure, financing, size, or other organizational aspects.

Although this study is oriented primarily toward the development of institutional support for medical research, it has been necessary to diverge from this relatively narrow point of view. Because of the intimate relationship between teaching and all forms of scientific research, special attention has been devoted to educational institutions. Moreover, many branches of science, while not specifically medical, have contributed essentially to medicine. Physiology and anatomy, for example, as well as chemistry and physics, have been studied as much or more for their own sake as for possible medical applications. Yet to ignore the history of these fields in the present context would be to eliminate much of the basis of modern medicine. At the same time, many of the institutional forms now prominent in the medical field have had earlier parallels in the other sciences, while many organizations and sources of financial support turned to medicine only after previously fostering other branches of learning.

Finally, it may be noted that the development of American educational and scientific institutions has received more detailed treatment than has been accorded to those in Europe. This study is in fact primarily one in American history; but this in turn can be understood and appreciated only by comparison and contrast with events in Europe. The history of medicine, science, or any other field of human endeavor in the United States has never since 1492 been isolated from the history of the world of which it is a part.

In the sixteenth and seventeenth centuries, Western civilization experienced a scientific revolution. Leading the movement of advance were changes in astronomy and physics represented by the replacement of the Ptolemaic geocentric cosmology by the Copernican heliocentric system, by Galileo's development of the laws of motion, and the Newtonian synthesis of terrestial and celestial mechanics into a universe subject throughout to the same natural laws. During this period modern chemistry was also beginning to develop as an integrated science with its own conceptual framework and methods. While individual chemists were adding to the body of empirical knowledge built up by earlier technology, Paracelsus's theory of the three principles—sulphur, mercury, and salt—underlying all matter gave way late in the seventeenth century to the corpuscular hypothesis of Robert Boyle. In botany and zoology, which had shown little progress since the days of Pliny, knowledge expanded rapidly. Improvements in the techniques of describing various species and discriminating between them culminated late in the seventeenth century in the works of John Ray on the principles of taxonomy and the natural history of plants, insects, birds, and fishes. The seventeenth century also witnessed the emergence of biology as a science distinct from natural history in the microscopic and experimental work of such men as Robert Hooke, Francesco Redi, and Antonj van Leeuwenhoek. The medical sciences similarly were profoundly affected by this scientific revolution, as the names of Andreas Vesalius in anatomy and William Harvey in experimental physiology testify. Indeed, many of the advances in chemistry and still more in botany and experimental biology were due to physicians, since these sciences were studied largely for their medical applications.

This scientific advance also involved a revolu-

tion in men's minds, for it required them to fit old observations into new frameworks. It depended on and fostered increased observation of the physical universe and new methods of investigation. While the theory of the experimental method was not new in the sixteenth century, scientists now began using it for answering specific questions rather than illustrating a system of logic.[1] Increasing scientific research in turn required the extension of facilities for research—space, instruments, collections, libraries, and means of publication—as well as of livelihood for the researchers. Today there is a galaxy of institutions designed to meet these needs: universities, research institutes, government agencies, industries, scientific societies and academies, foundations, and journals. They are the result of more than four centuries' growth.

The beginnings of the scientific revolution were centered in Padua and the other universities of northern Italy, which date from the thirteenth century, where relative freedom in teaching and thinking prevailed. Copernicus himself studied medicine there, and Vesalius was only the most famous of a series of outstanding Paduan medical scientists.[2] Moreover, the universities were beginning to provide their professors with certain facilities for demonstrative teaching and, incidentally, for research. Following Alessandro Benedetti's description of the ideal structure, published in 1502, a number of institutions in the sixteenth century provided temporary outdoor wooden amphitheaters for anatomical demonstrations. Then in 1594 Padua constructed for Hieronymous Fabricius ab Aquapendente the first permanent anatomical theater: it has been called the oldest university institute.[3] A student of Fabricius built a second one at Leyden the same year, and these two became the chief models for others during the following century.[4]

Similarly, the sixteenth century saw the formation of the first modern botanical gardens. Herb gardens for medicinal plants had of course existed during the Middle Ages, and in their lectures the medical professors at the University of Rome used plants from the one at the Vatican, which had been established in the thirteenth century. However, the Republic of Venice founded the first botanical garden as such in 1545 for the new professor of botany at Padua. Shortly thereafter the botanist Luca Ghini laid out gardens at Pisa and Florence for Duke Cosimo I di Medici. All three still survive as university establishments. A number of others followed before 1600, the first outside Italy being at Zürich in 1560 and Leyden in 1577. Not only were these gardens useful in teaching medical students: in some cases they stimulated research. Thus Andrea Cesalpino, professor of medicine and director of the botanical garden at Pisa, published in his *De Plantis* (Florence, 1583) the first real system of plant classification.[5]

Not all the scientific advances of the sixteenth century, however, emanated from universities. Copernicus spent most of his post-student life as a canon of Frauenburg cathedral in Prussia. Fracastoro, noted for his work on syphilis and epidemic diseases, lived a retired, country life. Paracelsus, founder of iatrochemistry, was a wanderer, and Ambroise Paré a military surgeon. During the seventeenth century, moreover, though the number of anatomical theaters and botanical gardens steadily increased, other new facilities to meet the expanding needs of science failed to develop. Experimental physics and physiology, chemistry, and microscopy became increasingly significant, but the universities rarely provided the necessary laboratories and instruments. Many leading seventeenth-century scientists were professors—Galileo, Torricelli, Borelli, Malpighi, and Baglivi in Italy, for example, Franciscus Sylvius (De le Boë) at Leyden, and Thomas Willis and Newton in England—but most of them carried on their investigations in their own homes at their own or a patron's expense.

There were exceptions. As early as 1612 a chemistry laboratory existed at the University of Giessen.[6] An observatory was founded at the University of Leyden in 1632,[7] and about thirty years later Sylvius reportedly persuaded the Cu-

[1] A. C. Crombie, *Robert Grosseteste and the origins of experimental science 1100–1700*, 295–296, Oxford, Univ. Press, 1953.

[2] Arturo Castiglioni, The medical school at Padua and the renaissance of medicine, *Annals of Medical History*, n.s. **7**: 214–227, 1935.

[3] Gottfried Richter, Das älteste Universitätsinstitut, *Forschungen und Fortschritte* **13**: 79–80, 1937.

[4] Arturo Castiglioni, The origin and development of the anatomical theater to the end of the Renaissance, *Ciba Symposia* **3**: 826–844, 1941.

[5] Wolfgang Born, Early botanical gardens, *Ciba Symposia* **11**: 1099–1109, 1949.

[6] Stephen d'Irsay, *Histoire des universités françaises et étrangères* **2**: 29, Paris, Auguste Picard, 1933–35.

[7] Giorgio Abetti, *The history of astronomy* (Betty B. Abetti, trans.), 321, New York, Henry Schuman, 1952.

rators to build a chemistry laboratory for him.[8] Oxford also established a similar laboratory in 1683.[9] More notable was the University of Altdorf, a creation of the city of Nürnberg. Here Professor Christian Sturm gave a course in experimental physics in 1683, the professor of astronomy had an observatory with instruments supplied by prosperous burghers, and in 1682 the University itself supplied the funds for a well-equipped chemistry laboratory.[10] The rarity of these exceptions, however, emphasizes how far the universities lagged. Even the provision of instruments for demonstration purposes in classroom lectures was only beginning at the end of the century. Though many professors engaged in original investigations, research as such was not considered to be the universities' job.[11]

Outside the universities some scientists, like Harvey, supported themselves and their research by private practice, or, like Leeuwenhoek, by business. Others, like Christian Huygens, Robert Boyle, and J. B. van Helmont, inherited, or married, wealth. Such fortuitous conjunctions of fortune, ability, and desire, however, could not satisfy the demands for research and teaching in science, and already special institutions were being organized for these functions. To bring the new learning of humanism to Paris, François I had established in 1531 six royal professorships in the University to lecture on Hebrew, Greek, and mathematics. Partly because of the University's hostility toward this new foundation, it soon developed into an autonomous institution, the Collège de France. In time the Collège acquired other chairs, including those in astronomy, geography, and medicine. The roll of professors includes several names distinguished in science—more than can be said for the archconservative University of Paris. But unfortunately even the Collège in the seventeenth century was in a declining state.[12]

Unlike the University of Paris, the two English universities at the time of Thomas Linacre early in the sixteenth century had been receptive to humanism. After the middle of the century, however, the center of interest shifted to London, where Elizabethan scientists and men of affairs were much interested in the practical application of scientific knowledge and at the same time in enriching science with the empirical technology of artisans. Hence came the large number of scientific books published in the vernacular during the sixteenth century, and hence also a campaign for public instruction in science. As a result, the first Mathematical Lecturer of the City of London was inaugurated in 1588, with the encouragement of the Privy Council and the financial support of a group of London merchants. Lasting only a few years, this innovation was superseded in 1598 by Gresham College, which was founded by a legacy from Elizabeth I's financial adviser, Sir Thomas Gresham. With its handsomely paid professors of law, rhetoric, divinity, music, physic, geometry, and astronomy, the College soon became an important center of teaching and research as well as a meeting place for scientific discussion.[13]

The desire to institute training in science and technology exhibited by these Londoners in the sixteenth century continued into the seventeenth. A number of men, increasingly critical of the universities' slow progress, proposed scientific colleges of various types combining practical teaching with research. Others recommended institutions designed solely for the advancement of learning. Notable among the latter was Francis Bacon's utopian "Salomon's House," described in *New Atlantis* (1626), with its hierarchy of scientists and fully equipped laboratories and collections for every type of scientific investigation.[14]

[8] Michael Foster, *Lectures on the history of physiology*, 147, Cambridge, Univ. Press, 1901.

[9] R. T. Gunther, The first public chemical laboratory in England, *Nature* **119**: 492, 1927. Earlier Peter Stahl, a protégé of Boyle, had given a laboratory course in chemistry at Oxford for several years outside the University. G. H. Turnbull, Peter Stahl, the first public teacher of chemistry at Oxford, *Annals of Science* **9**: 265–270, 1953.

[10] Martha Ornstein, *The rôle of scientific societies in the seventeenth century*, 230–231, 3rd ed., Chicago, Univ. of Chicago Press, 1938.

[11] Irsay, *op. cit.* **2**: 1–73; Ornstein, *op. cit.*, 213–263; Phyllis Allen, Scientific studies in the English universities of the seventeenth century, *Jour. Hist. of Ideas* **10**: 219–253, 1949; Maurice Daumas, *Les instruments scientifiques aux XVII^e et XVIII^e siècles*, 180–182, Paris, Presses universitaires de France, 1953.

[12] Irsay, *op. cit.* **1**: 270–274; **2**: 63; Ornstein, *op. cit.*, 225–226.

[13] Francis R. Johnson, *Astronomical thought in Renaissance England, passim*, Baltimore, Johns Hopkins Press, 1937; *idem*, Gresham College: precursor of the Royal Society, *Jour. Hist. of Ideas* **1**: 413–438, 1940; *idem*, Thomas Hood's inaugural address as Mathematical Lecturer of the City of London (1588), *ibid.* **3**: 94–106, 1942; Dorothy Stimson, *Scientists and amateurs: a history of the Royal Society*, 26–30, New York, Henry Schuman, 1948; Irsay, *op. cit.* **1**: 274–277.

[14] Ornstein, *op. cit.*, 43, 61, 63n, 99n, 168, 264–270; Stimson, *op. cit.*, 8–25.

While Bacon's ideal was more comprehensive than any research institute even now existing, a number of smaller groups interested in natural philosophy, forerunners of the national scientific academies, were already active. Unlike Gresham College they were not founded as teaching institutions. In England, for example, during the third quarter of the sixteenth century the home of the country's leading mathematical scientist, John Dee, with his laboratory and scientific library—the best in Britain—, was in effect the nation's center of scientific activity. Somewhat later Gresham College often served as a meeting place for amateurs of natural philosophy. Another group, formed about 1645, met weekly in various places about London to discourse on physics, astronomy, anatomy, physiology, and other "Natural Experiments." During the Interregnum, most of them moved to Oxford, where with other "inquisitive Persons" they formed the Oxford Philosophical Society in 1651. With the Restoration, however, the London group, recruited by many from Oxford, formed a new association. In 1662 they received a charter as the Royal Society of London.[15]

The purpose of the Royal Society was to advance the new experimental science. Toward this end it collected instruments and rarities and appointed Robert Hooke curator of experiments. At the weekly meetings the fellows discussed scientific problems and witnessed demonstration experiments performed by Hooke or another member. Lacking outside support, the Society remained for years financially weak. Hooke, the secretary, a clerk (Edmond Halley from 1676 to 1698), and an occasional temporary appointee received inadequate salaries or small honoraria, but the Society was otherwise unable to support a scientific staff, nor could it provide laboratories or subventions for research. Except for the occasional loan of instruments the members continued to rely primarily on their own resources for their own experimental investigations. The Royal Society as such did not engage in research. Rather it encouraged research among its fellows and others by assigning certain topics to particular individuals, by discussion, advice, and criticism, by the recognition that election to fellowship accorded, and, beginning with the appearance of John Evelyn's *Silva* in 1664 and the *Philosophical Transactions* in 1665, by publication. Despite its manifold contributions, therefore, it did not measure up to the type of institute envisioned by Bacon.[16]

Elsewhere, however, academies more nearly approaching the "House of Salomon" were established during the seventeenth century. In Italy, the root of the movement went back to the Platonic Academy of fifteenth-century Florence. In this and other early Renaissance academies the range of interests was encyclopedic, but during the sixteenth century specialization supervened and the organizations became more formal. Most of the Italian academies were interested in literary or artistic subjects, but in 1560 Giambattista della Porta of Naples organized a group of friends interested in experimental science as the so-called Academia Secretorum Naturae. This the Church soon closed.[17]

More significant was the Accademia dei Lincei founded by Duke Federigo Cesi about 1601. Cesi's grandiose plans for a world-wide network of research establishments manned by scientists leading a sort of nonclerical monastic life never materialized, but the Lincei met regularly for discussion and published several scientific works. Then, in 1657, Leopold di Medici formed the famous Accademia del Cimento. Using his extensive collection of instruments as a nucleus, Leopold provided the scientists, who experimented in common, with all the necessary equipment and he defrayed all their expenses. The distinguished roster of the academy included the physiologist Gian Alfonso Borelli, the anatomist Niels Stensen (Steno), and the embryologist Francesco Redi. In 1666 the academy published a notable account of its work, chiefly in experimental physics. Here was a genuine research institute, but it depended entirely on Leopold's support, and

[15] Johnson, *Astronomical thought*, 135–139; *idem*, Gresham College; Stimson, *op. cit.*, 37–54; R. H. Syfret, The origins of the Royal Society, *Notes and Records of the Royal Society of London* **5**: 71–137, 1948; Henry Lyons, *The Royal Society 1660–1940: a history of its administration under its charters*, 1–33, Cambridge, Univ. Press, 1944.

[16] Ornstein, *op. cit.*, 91–138; Stimson, *op. cit.*, 54–115; Lyons, *op. cit.*, 34–115; *The record of the Royal Society of London for the Promotion of Natural Knowledge*, 23–45, 4th ed., London, Royal Society, 1940.

[17] Frances A. Yates, *The French academies of the sixteenth century*, 1, London, Univ. of London, Warburg Institute, 1947; George E. Hale, National academies and the progress of research, *Science* **38**: 684–685, 1913; Douglas McKie, Scientific societies to the end of the eighteenth century, Allan Ferguson, ed., *Natural philosophy through the 18th century and allied topics (Philosophical Magazine*, Commemoration Number), 133, London, Taylor & Francis, 1948.

when he withdrew this in 1667, perhaps in return for his cardinal's hat, the academy disbanded. Its end marks the passage of primacy in science to the north of the Alps.[18]

In France as in Italy, the earliest academies were encyclopedic in nature. Thus the Académie de Poésie et de Musique, which was chartered in 1570, comprehended natural philosophy and mathematics as well as music and poetry in the modern sense. However, the members were apparently more interested in discussion than experiment. In the seventeenth century projects for encyclopedic academies gave way before the increasing tendency toward specialism. By 1635, when Richelieu founded the Académie Française, private organizations of experimental scientists had already appeared. Of particular significance was the group revolving about Marin Mersenne beginning in the 1620's, which became during the next decade a more or less formal academy. An indefatigable correspondent, Mersenne kept in touch with scientists throughout Europe and also with rich courtiers and bourgeois who might offer scientists financial support.[19]

After Mersenne died in 1648, others carried on this tradition, notably the wealthy Habert de Montmor, whose academy was formally constituted in 1657, some months after the Accademia del Cimento. Here men met for discussion and also for performing experiments, with their own instruments by way of demonstration, or with the collection provided by Montmor himself. Before long, however, clashing personalities and ideas caused dissension. Moreover, the serious scientists, who wanted less talk and more work, felt the need of more adequate facilities for research. Believing that only the royal purse could satisfy their requirements, a number of savants applied to Colbert for financial support, pointing to the Royal Society recently established in London and arguing that an experimental scientific institution would not only add luster to the king's name but also prove of great practical value to the nation. As a mercantilist anxious to develop the self-sufficiency and strength of France, as a statesman bent on increasing centralized control of French society, and as a minister who to maintain his own power had continually to flatter an inordinately vain monarch, Colbert proved susceptible to these appeals. Obtaining the support of Louis XIV, he founded the Académie Royale des Sciences in 1666.[20]

Of all the seventeenth-century organizations the Académie des Sciences came closest to fulfilling Bacon's ideal. The membership was strictly limited to working scientists, and Colbert was careful to pick the best, among them Christian Huygens, Edmé Mariotte, G. D. Cassini, and Olaus Römer. The king granted pensions to the academicians, provided a laboratory and astronomical observatory as well as a meeting place, and defrayed the running expenses. In essence it was a general scientific research institute. Theoretically the scientists worked in common, as in the Accademia del Cimento, but in fact it generally became known who was responsible for particular achievements. In the France of Louis XIV, government support also meant strict government control, but fortunately Colbert, sensing the ultimate value of pure research, allowed the scientists considerable freedom to choose their own subjects of investigation. While their most notable contributions were in astronomy, they also made investigations in botany, chemistry, anatomy, and physiology, including experiments on blood transfusion. After Colbert died in 1683, however, his successor demanded more "useful" work. Because of this attitude, which together with the revocation of the Edict of Nantes, drove Huygens and Römer away, the Académie declined.[21]

Besides the English, Italian, and French academies the seventeenth century also witnessed the establishment of a number of other similar institutions. Joachim Jungius founded the short-lived Societas Ereunetica at Rostock in 1622, the first German scientific society. Thirty years later, in 1652, the Schweinfurt physician Johann Lorenz Bausch founded the Academia Naturae Curiosorum to encourage experimental science by discussion among the members and especially by publication. In 1670 the society inaugurated its periodical *Miscellanea Curiosa*, and seven years later Leopold I, the Holy Roman Emperor, con-

[18] Ornstein, *op. cit.*, 74–90; Abraham Wolf, *A history of science, technology, and philosophy in the 16th & 17th centuries*, 55–59, 2nd ed., London, George Allen & Unwin, 1950; A. R. Hall, *The scientific revolution 1500–1800*, 188–191, London, Longmans, Green, 1954.

[19] Yates, *op. cit.*, 14–35, 95–104, 275–297; Harcourt Brown, *Scientific organizations in seventeenth century France (1620–1680)*, 1–63, Baltimore, Johns Hopkins Press, 1934; Pierre Gauja, L'Académie Royale des Sciences (1666-1793), *Revue d'histoire des sciences* **2**: 293–297, 1949.

[20] Brown, *op. cit.*, 64–154; A. J. George, The genesis of the Académie des Sciences, *Annals of Science* **3**: 372–401, 1938.

[21] Gauja, *loc. cit.*, 299–301; Wolf, *op. cit.*, 63–67; Ornstein, *op. cit.*, 139–164.

firmed its statutes. In 1687 he extended its privileges further and granted the title, Sacri Romani Imperii Academia Caesareo-Leopoldina Naturae Curiosorum. The society continues today at Halle as the Deutsche Akademie der Naturforscher.[22]

During the eighteenth century the academic movement extended. The new national societies tended to follow the French example rather than the English, receiving the governmental financial support which made possible the provision of facilities for research. First among the important new foundations was the Akademie der Wissenschaften at Berlin founded in 1700 as the Societas Regia Scientarium by the Elector of Brandenburg after years of persevering agitation by Leibniz. Despite many initial difficulties, the society early acquired an astronomical observatory; later an anatomical theater, mineralogical collection, and botanical garden were added. Under Frederick the Great royal support increased markedly, and in addition to a meeting hall the monarch constructed a laboratory where the Academy's salaried chemist engaged in research.[23]

Leibniz's efforts to found scientific academies extended beyond Berlin, and he was thus in part responsible for the organization of the Russian Academy of Science, established in St. Petersburg in 1725 for both teaching and research. As in France, the government paid salaries to the academicians, who were limited to fifteen, and provided laboratories and other facilities for their investigations.[24] In Sweden, a small group primarily interested in practical applications organized the scientific academy in 1739 and received royal patronage two years later. With money obtained from a monopoly of publishing the Swedish almanac, the academy completed an observatory in 1753, but in other respects its activities depended on the work that its members, numbering one hundred, performed outside.[25]

In addition to these and other national academies, the eighteenth century also witnessed the proliferation of similar organizations at the local level. In Germany, Göttingen, Erfurt, Mannheim, and Munich all gave birth to scientific academies during the 1750's. In pre-Revolutionary France provincial academies were even more common and did notable work. In Great Britain, the most important developments were in Scotland and the industrial midlands. Of particular significance were the philosophical society founded in 1731 that became the Royal Society of Edinburgh in 1783; the Lunar Society of Birmingham, founded about 1766, which had a notable though rather brief career; and the Manchester Literary and Philosophical Society, founded in 1781. The last, distinguished in the nineteenth century for providing John Dalton with space to work, became the prototype of many provincial institutions and despite severe war damage still continues. More typical, perhaps, was the Derby Philosophical Society, established in 1784 and composed largely of local worthies "of moderate means and moderate scholarship."[26] By bringing together manufacturers, scientists, and men of letters for discussion and in some cases by publication, such societies helped to promote learning and also to speed the technological developments of the Industrial Revolution. With rare exceptions, however, they were unable to offer researchers financial support.[27]

Two local organizations, one in Bologna and the other in Frankfurt am Main, as exceptions to the general type deserve special mention. In 1690 Luigi Ferdinando Marsili, a wealthy amateur and patron of the Accademia digli Inquieti, bequeathed his valuable collection of natural objects, scientific instruments, manuscripts, and books to the Senate of Bologna, on condition that it pro-

[22] *Ibid.*, 167–175; Emil Abderhalden, ed., *Festgabe aus Anlass der 250. Wiederkehr des Tages der Erhebung der am 1. Januar 1652 gegründeten privaten Akademie zur Sacri Romani Imperii Academia Caesareo-Leopoldina Naturae Curiosorum durch Leopold I. (7. August 1687)*, 5–49, Halle, 1937.

[23] Ornstein, *op. cit.*, 177–197; Adolf Harnack, *Geschichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin* **1**: 485–487, Berlin, Reichsdruckerei, 1900.

[24] Alexander Lipski, The foundation of the Russian Academy of Sciences, *Isis* **44**: 349–354, 1953. See also, Boris N. Menshutkin, *Russia's Lomonosov, chemist, courtier, physicist, poet* (J. E. Thal and E. J. Webster, trans.), *passim*, Princeton, Princeton Univ. Press, 1952.

[25] Rob. E. Fries, *On the origin and foundation of the Royal Swedish Academy of Science*, 3–7, Stockholm, 1940; Arne Holmberg, *Some notes on the Royal Swedish Academy of Science (Kungl. Svenska Vetenskapsakademien)*, 5–7, Stockholm, 1939.

[26] Eric Robinson, The Derby Philosophical Society, *Annals of Science* **9**: 363, 1953.

[27] McKie, *loc. cit.*, 137–141; S. F. Mason, *Main currents of scientific thought: a history of the sciences*, 212, 228–229, New York, Henry Schuman, 1953; Robinson, *loc. cit.*, 359–367; Donal Sheehan, The Manchester Literary and Philosophical Society, *Isis* **33**: 519–523, 1941; H. J. Fleure, The Manchester Literary and Philosophical Society, *Endeavour* **6**: 147–151, 1947.

vide a suitable home. The Senate purchased the Poggi palace and in 1714 the Institute of Sciences, as Marsili's foundation was known, formally opened. In accordance with the designs of the founder, its purpose was to promote research and experiment in the natural sciences, under the direction of professors whose teaching was to be distinct from that of the university. From its erection the Institute cultivated chemistry, physics, natural history, astronomy (it obtained an observatory in 1725), military architecture, geography, and navigation. In time anatomy and archaeological studies were added. Taking an active role in the research work was the Academy of Sciences of the Institute, successor of the Inquieti, many of whose members were Institute professors. Throughout the century the Institute, remaining separate from the university, continued to grow and flourish. During the Revolutionary and Napoleonic eras, however, the two were joined and the Institute lost its independent existence.[28]

Of more direct consequence to medical research was the foundation of Johann Christian Senckenberg in Frankfurt am Main. This unusual physician and philanthropist, one of the earliest medical graduates of Göttingen, set up an endowment of 95,000 gulden in 1763, one-third for a hospital and two-thirds for a medical institute. Sensing correctly that his fellow townsmen would support the hospital but fail to understand that the greater benefit would eventually come from research, Senckenberg devoted his own energies primarily to building his institute. He obtained a great estate at Eschenheimer Tor and there built an anatomical theater, chemical laboratory, and botanical garden, all to be administered by a special board. Though it engaged in some medical teaching, the primary function of the Senckenberg Institute was research. Especially notable was the work of Carl Weigert, who, denied the chair of pathology at Leipzig in succession to Julius Cohnheim because he was a Jew, accepted the post of Director of the Senckenberg Institute in 1885. There he stayed until his death in 1904, teaching and inspiring a limited number of special students in his laboratory and quietly pursuing his research.

Senckenberg also left to his Institute a collection of minerals and fossils. These were of less interest to the medical scientists, but led eventually to the formation of the Senckenbergische Naturforschende Gesellschaft in 1817 and its offshoot, the Physikalische Verein, in 1824. From these developed in turn a number of institutes in the natural sciences. Founded primarily for research, they eventually took up teaching as well and finally were joined to the University of Frankfurt, a new foundation dating only from 1914.[29]

The national and local academies and societies of the seventeenth and eighteenth centuries had been founded to encourage the growth of science by direct observation and experiment rather than scholastic speculation and argument at a time when most universities, except through the provision of anatomical theaters and botanical gardens, were failing to do so. The academies afforded invaluable opportunities for discussion and mutual encouragement. They disseminated scientific information: early scientific periodicals were quite generally associated with academies, and they also sponsored many books. Moreover, a number of academies on the Continent persuaded their respective royal patrons to establish observatories staffed by salaried astronomers under the direction of the academies themselves, and in England the Royal Observatory, although founded independently, worked closely with the Royal Society. Less commonly the Continental academies provided pensions and subventions for research in other fields as well.

Indispensable as the academies and societies have been in the development of science, the number of members and their support were limited. The primary avenue for the support of research in the nineteenth century was to come not through the further development of such organizations but rather through the reformation of educational institutions. Indeed any large scale development of science necessarily depended on enlarging and improving educational facilities, particularly as the advance of science made it increasingly specialized.

Although the universities of northern Italy were the leading scientific educational institutions of the seventeenth century, in succeeding years they suffered disastrously from increasing church control and the loss of their old freedom in teaching and learning. The French universities, weighed

[28] Ornstein, *op. cit.*, 219; M. E. Costa *et al.*, *L'Université de Bologne autrefois aujourd'hui* (A. de Carli, trans.), 30–36, Bologna, Nicola Zanichelli, n.d.

[29] Ludolph Brauer *et al.*, *Forschungsinstitute: ihre Geschichte, Organisation und Ziele* **2**: 154–158, 238–242, Hamburg, Paul Hartung, 1930; E. K. Dunham and C. A. Herter, The collected works of Carl Weigert, *Jour. Amer. Medical Assoc.* **48**: 412–415, 1907.

down by centuries of tradition and emphasis on theological studies, contributed little or nothing to science. In England, despite the establishment of a number of new chairs, the unreformed universities, affected like the Royal Society with the prevailing conservatism and corruption of British ruling circles, tended to stagnate. So little disposed to reform themselves from within, these ancient foundations seemed to need prodding from new and more vigorous forces without.[30]

It is conceivable that the academies themselves might have performed this function. Both the Royal Society of Sciences founded at Upsala in 1710 and the Danish academy of sciences founded in 1742 supported professorial chairs in conjunction with the local universities.[31] In Bologna, as we have seen, Marsili founded a new research and teaching institute. The Russian Academy of Science also performed both functions. It was here in 1752 that M. V. Lomonosov inaugurated the first practical laboratory course in chemistry, an experiment that proved short-lived.[32] Fundamentally, however, the difficulty was that no one was yet ready to support on a sufficiently extensive scale research institutes where the necessary teaching programs might develop. Rather the solution had to come by the gradual evolution of research facilities in educational foundations. It was primarily in new ones that a truly cordial attitude toward science first appeared.

In England during the eighteenth century the best teaching in the sciences might be found in independent schools like the Hunters' in London and in the dissenting academies. Excluded from the universities by the Clarendon Code of 1662, Nonconformists had set up their own private educational institutions. Like Oxford during the Commonwealth, they not only taught divinity and classics, but were also hospitable toward the sciences. While they did not provide facilities for research or necessarily expect it of their teachers, it is among their teachers, students, and supporters, men like Joseph Priestley, Thomas Percival, and John Dalton, that many of England's most important scientists and physicians of the later eighteenth century may be found.[33]

[30] Irsay, *op. cit.* **2**: 107–108, 112–116; Dorothy M. Turner, *History of science teaching in England*, 45–50, London, Chapman & Hall, 1927.

[31] Irsay, *op. cit.* **2**: 90.

[32] Menshutkin, *op. cit.*, 121–130.

[33] John F. Fulton, The Warrington Academy (1757–1786) and its influence upon medicine and science, *Bull. Inst. Hist. of Medicine* **1**: 50–80, 1933; Stimson, *op. cit.*, 165–168.

Elsewhere in Britain, the Scottish universities, which were not under Anglican control, also advanced the teaching of science, surpassing the dissenting academies. Particularly was this true in chemistry, taught as part of the medical course, where Joseph Black followed William Cullen, first at Glasgow and then at Edinburgh. Across the Channel, Leyden also was noted especially in the early 1700's for chemistry and even more for clinical instruction under the great teacher Hermann Boerhaave. Indeed, it was the example of Leyden that led to the development of Edinburgh and also the so-called old Vienna school under Gerard van Swieten in the second half of the century.[34]

The dissenting academies of England, however, with rare exceptions lacked the strength to establish themselves as permanent institutions. Early in the nineteenth century, increasingly on the defensive, they became more narrowly theological. Despite their contributions to their own era, they ultimately proved unable to force a general reform in English education. Leyden, Edinburgh, and Vienna under van Swieten proved more influential in modernizing instruction, especially in medicine—which as late as 1800 was still the main avenue of approach to a professional career in science[35]—but these schools were famous primarily for teaching, rather than research. Even Black, the only Edinburgh chemistry professor who made contributions of the first order, completed all his important work shortly after obtaining his medical degree, before taking the post at the Scottish capital. The roots of the great contribution of the nineteenth-century German universities, the combination of teaching and research, must be sought in Germany itself.

The pioneer in this movement was the university at Halle, founded in 1694 by the Elector of Brandenburg. Established partly in protest against orthodox Lutheranism, the university was particularly notable in its early years for its faculties of theology and law. The Elector also contemplated a chemical laboratory, zoological and botanical gardens, workshops, museums, and other facilities. Though sufficient money was unfortunately not forthcoming, the influence of such eminent professors and investigators as G. E.

[34] Irsay, *op. cit.* **2**: 78–85; F. Sherwood Taylor, The teaching of the physical sciences at the end of the eighteenth century, Ferguson, *op. cit.* (note 17), 155–160.

[35] *Ibid.*, 144–148.

Stahl and Friedrich Hoffmann kept Halle for some years the leading school in Germany.[36]

The model university of the eighteenth century, however, was Göttingen, founded by the government of Hanover in 1734, which charged the professors with a duty not only to teach but also to engage in scientific research. For their benefit the university founded a series of learned journals and established an excellent library. It provided an observatory and other physical instruments, dissecting rooms, anatomical collections, an anatomical theater, a botanical garden, a hospital with an obstetric division, and a pharmacy. Although the founders of the university looked upon teaching and research as two distinct functions, the professors gradually combined the two in private courses, forerunners of the seminar, where they presented the results of their work and stimulated a taste for independent investigation among the students. The first university planned as a research center, Göttingen provided an opportunity worthy of the genius of an Albrecht von Haller.[37]

The examples set by Leyden and Göttingen slowly influenced the development of many European universities during the eighteenth century, but to reform the inherited reactionary outlook of those in France required a cataclysmic event. Only with the French Revolution, which led to the complete reconstitution of the ancient educational and scientific organization of the nation, did modern science at last become important in French curricula. Successive governments changed the old foundations radically, and at the same time created new scientific and technological institutions such as the Ecole Polytechnique, the Ecole Normale, and the Conservatoire des Arts et Métiers. Two institutions stood foremost under the new regime, the Muséum d'Histoire Naturelle, successor to the Jardin du Roi, and the Collège de France. Under the inspiration of a group of brilliant professors at these two centers, France at the beginning of the nineteenth century led the world in the natural sciences. To show the influence of this stimulating new age in medicine, it is only necessary to cite such names as Bichat, Magendie, Broussais, Corvisart, and Laënnec.[38]

Unfortunately, the new French educational system, except at the very top, did not combine teaching and research. As it had been before the Revolution, the professors' function was to pass on accepted knowledge. Those whose inner compulsion drove them to investigate the phenomena of nature, if they aspired to more than a miserable garret or cellar, had to rely on their own pockets as well as their own brains. Until he reached the Collège de France, Claude Bernard had to devise and equip a private laboratory for his physiological research; even after he reached the summit, his facilities were sadly inadequate. When Pasteur became director of scientific studies at the Ecole Normale in 1859, the only space for his scientific installation was in the attic, and he had no assistants of any kind. France produced a number of brilliant scientists throughout the nineteenth century, but she soon lost her primacy.

The advance of science after 1800 could no longer depend on the wealthy amateur or dedicated practitioner. Concerted and consistent enlargement of the body of natural knowledge required more extensive facilities for research and for training young men in the attitudes and techniques of research. In medicine the hospital ward and dead-house had become general in the eighteenth century, and we still honor eponymously a number of nineteenth-century British physicians who did excellent work with these facilities. But the future of medicine lay primarily in the laboratory. Here France and Great Britain lagged behind Germany, where the universities developed laboratory institutes and steadily led scientific advance. Alluding in the dark days of 1871 to France's former position of leadership, Pasteur noted with sorrow, "Whilst Germany was multiplying her universities, establishing between them the most salutary emulation, bestowing honours and consideration on the masters and doctors, creating vast laboratories amply supplied with the most perfect instruments," his own country, a victim of political instability, had "lived on her past, thinking herself great by the scientific discoveries to which she owed her material prosperity, but not perceiving that she was imprudently allowing the sources of those discoveries to become dry. . . ."[39]

[36] Irsay, *op. cit.* **2**: 68–73; Theodor Puschmann, *A history of medical education* (E. H. Hare, trans.), 389–390, London, H. K. Lewis, 1891.

[37] Irsay, *op. cit.* **2**: 90–103; Henry E. Sigerist, *The great doctors: a biographical history of medicine* (Eden and Cedar Paul, trans.), 194–196, New York, W. W. Norton, 1933.

[38] Irsay, *op. cit.* **2**: 145–178; L. Pearce Williams, Science, education and the French Revolution, *Isis* **44**: 311–330, 1953.

[39] Irsay, *op. cit.* **2**: 290–297; René Vallery-Radot, *The life of Pasteur* (Mrs. R. L. Devonshire, trans.), 42, 84, 152–153, 194–196, Garden City, Garden City Publishing Co., n.d. The quotation is on p. 196.

In the development of German universities the most distinct step forward since the foundation of Göttingen came in 1810 when King Frederick William III of Prussia founded the University of Berlin. Following the conceptions of Wilhelm von Humboldt, the minister of education, the royal councillors intended the university not as a simple teaching institution, or even as a teaching institution where research, as at Göttingen, held an honorable place. Berlin, in sharp contrast to the system of state schools that Napoleon was setting up contemporaneously in France, was founded on the principle of combining teaching and research. Humboldt believed that professors must be independent scholars with liberty to teach freely, not only for the sake of their students, but also because teaching alert young minds was a necessary stimulus to research.

Humboldt envisioned the university, the Berlin Academy, and the so-called "*Hülfsinstitute*," as a triad of learned institutions, each independent of the other yet linked by interlocking membership and all under the protection and care of the state. Humboldt's *Hülfsinstitute*—the library, observatory, anatomical theater, laboratories, and other facilities necessary for practical teaching and scientific research—were not independent research institutes in the modern sense but rather administratively separate establishments serving the needs of both academy and university and subject to their control indirectly through the state. Independent *Hülfsinstitute*, however, did not materialize. Instead the government attached the existing institutes in Berlin, which the academy had hitherto developed and directed, to the university. Within a decade the new foundation had institutes of surgery, gynecology, psychiatry, anatomy, and zoology, medical and surgical clinics and policlinics, a botanical garden, an observatory, and seminaries in theology and philology.[40]

The actual laboratory equipment of the new university was still meager, and the great development of teaching research laboratories for which Germany later became so justly renowned first occurred elsewhere. They owed their establishment primarily to the persistent efforts of a few devoted scientists. A pioneer in this movement, and yet typical of its early days, was Justus von Liebig. Born in 1803, Liebig studied with Gay-Lussac in Paris and in 1824 received a call to Giessen. Two years later, at the age of twenty-three, he became full professor of chemistry. This subject had long held an honorable place in the medical curriculum, and chemistry laboratories in universities were now by no means rare. They were small, set up for the professors' private use and for preparing lecture demonstrations. A few men, like Berzelius, admitted a small number of selected students. Laboratory instruction on any extensive scale, however, did not exist. At Giessen, Liebig at first had no laboratory budget and had to furnish his own equipment. An inspiring and painstaking teacher as well as an extremely productive investigator, he soon founded a large "school," and the university was at last reluctantly forced to provide him with adequate teaching and research facilities. His laboratory served as the first model of the modern university institute.[41]

One of the reasons for Liebig's success was that he developed chemistry as an independent branch of study rather than an adjunct to medicine. The earliest of the new institutes in a medical science was formed at Breslau. Through the influence of Goethe and Alexander von Humboldt the university in 1823 called Jan Evangelista Purkynĕ, a Czech six years out of medical school, to the chair of physiology. Much to his colleagues' distress, Purkynĕ began illustrating his lectures with demonstrations. Even worse, he established a physiological laboratory in an unused corner of the college building and started animal experimentation. To the rest of the faculty such work seemed irrelevant, besides causing a stench, so Purkynĕ transferred his laboratory to his own home. Like Liebig, however, Purkynĕ was a brilliant investigator and teacher, and students began coming from all over Germany to attend his classes and work in his laboratory. Gradually his colleagues relented and the university began to support his research. It took Purkynĕ nine

[40] Irsay, *op. cit.* **2**: 185–196; Friedrich Paulsen, *The German universities and university study* (Frank Thilly and William W. Elwang, trans.), 51–54, New York, Charles Scribner's Sons, 1906; Harnack, *op. cit.* (note 23) **1** (*2*): 586–587, 594–603; Wilhelm von Humboldt, uncompleted memorandum, Über die innere und äussere Organisation der höheren wissenschaftlichen Anstalten in Berlin, in *ibid.* **2**: 361–367.

[41] Ernst von Meyer, *A history of chemistry from earliest times to the present day* (George McGowan, trans.), 263–265, 2nd ed., London, Macmillan, 1898; Irsay, *op. cit.* **2**: 283; Paulsen, *op. cit.*, 58, 218; Julius Schiff, Das erste chemische Institut der Universität Breslau, *Archiv für die Geschichte der Naturwissenschaften und der Technik* **9**: 29–38, 1920; Forest R. Moulton, ed., *Liebig and after Liebig: a century of progress in agricultural chemistry* (American Association for the Advancement of Science, Publication No. 16), 1–17, Washington, 1942.

years, from 1823 to 1832, to get a modern microscope, but in 1839 the Prussian government constructed a special building for him, the first physiological institute. Though his most productive years had passed by then, the new laboratory set a standard for other universities and younger men to follow.[42]

Following the examples set by Liebig and Purkynĕ, other universities in time established institutes in chemistry, physiology, and other sciences. Especially notable among the earlier ones were those of Rudolf Virchow in pathology, founded at Berlin in 1856; Ferdinand Cohn in botany, Breslau, 1866; Carl Ludwig in physiology, Leipzig, 1869; E. F. Hoppe-Seyler in physiological chemistry, Strassbourg, 1872; and Max von Pettenkofer in hygiene, Munich, 1879. The early institutes usually formed about some outstanding teacher and scientist, often one who started, like Liebig and Purkynĕ, by setting up his own laboratory and attracting thereby an increasing number of students. Then, as laboratories became more common, universities had to establish facilities in order to attract outstanding men. Robert Bunsen, for example, insisted on a new chemistry institute at Breslau before accepting a professorship in 1851—and the next year he left for Heidelberg. Similarly, Virchow returned to Berlin in 1856 only on condition that a special building be erected for his pathological institute.

Thus throughout Germany the many universities set up dozens if not hundreds of institutes in the second half of the nineteenth century. Students flocked from all over Europe, moving from one city to another seeking the best men in each field. Committed to the combination of teaching and original research and to *Lehrfreiheit* (at least in science), working on the principle first developed in theological, philological, and historical seminars that advanced students should not only learn about but participate in their professors' investigations, and supported by the recognition and prestige accorded to learning for its own sake as well as for its practical benefits, the German universities turned out large numbers of well trained physicians and scientists. In so doing they also provided adequate laboratory facilities with plenty of assistants where the best of those scientists might pursue their own investigations according to the bent of their spirits. Thus Germany seized world leadership in scientific endeavor.[43]

Though several neighboring European nations —Austria, Sweden, Denmark, Switzerland, and the Netherlands—closely followed Germany in establishing scientific institutes, France and England lagged behind. In the latter country the ancient universities remained unreformed until the middle of the century, and the dissenting academies had already declined. For some years the most hopeful development seemed to be the mechanics' institutes, which were designed to give popular and primarily practical scientific instruction to workingmen. First started in Glasgow in 1796, they spread widely during and after the 1820's. By 1850 there were reportedly more than 600 with over 100,000 members. Though the movement declined thereafter, chiefly from lack of money and the competition of new and better foundations, some of the mechanics' institutes, among them Birkbeck College in London, have survived in changed form. Meanwhile they had done much to popularize scientific knowledge in England.[44]

One establishment of this genre, the Royal Institution, deserves special mention. Founded by Count Rumford in 1799 to promote useful inventions and the education of artisans, it soon attracted to its lectures a more fashionable class and became in fact a small research institute in the physical sciences. It had the best research laboratory then available in England, and is notable for having supported among others Humphry Davy and Michael Faraday. This institution, however, was, and in some respects still is, unique.[45]

[42] Henry J. John, Jan Evangelista Purkynĕ, Czech scientist and patriot (1787–1869), *Proc. Royal Soc. Medicine* **46**: 933–940, 1953; *Allgemeine deutsche Biographie* **26**: 718–723.

[43] The literature on the significance of the development of laboratory research in the German universities during the nineteenth century is extensive. See, for example, Irsay, *op. cit.* **2**: 285–290; William H. Welch, The evolution of modern scientific laboratories, *Bull. Johns Hopkins Hospital* **7**: 19–24, 1896; Abraham Flexner, *Medical education in Europe* (Carnegie Foundation for the Advancement of Teaching, Bulletin No. 6), 3–12, 73–112, New York, 1912; *idem, Medical education, a comparative study*, 31–36, New York, Macmillan, 1925; Richard M. Pearce *et al., Medical research* (J. McKeen Cattell, ed., Science and Education, vol. 2), 1–88, *passim*, New York, Science Press, 1913; Paulsen, *op cit.*, 50–67, 163–171, 212–230, *passim;* Florian Cajori, *A history of physics in its elementary branches including the evolution of physical laboratories*, 392–393, revised ed., New York, Macmillan, 1929.

[44] Turner, *op. cit.* (note 30), 59–66; Mason, *op. cit.* (note 27), 356–357.

[45] Thomas Martin, *The Royal Institution*, London, Longmans, Green, 1942; Stimson, *op. cit.* (note 13), 183–185; Cajori, *op. cit.* 402–403.

Curiously, Davy had come there from one of the earliest medical research institutes, Dr. Thomas Beddoes's Pneumatic Institution in Clifton near Bristol. Founded in 1798 with the support of James Watt and Thomas Wedgwood to test the medicinal effect of inhaling various gases, the institution is remembered chiefly for Davy's work on nitrous oxide. Had his suggestion that it be used for surgical anesthesia been taken up, the institute's contribution to medicine would indeed have been memorable. Shortly after Davy left to join the Royal Institution in 1801, the Pneumatic Institution ceased to exist.[46]

While mechanics' institutes helped spread interest in science, adequate provision for research in Great Britain had to await the founding of new universities and the reform of the old ones. During the first half of the nineteenth century, despite increasing attack, Oxford and Cambridge remained rigidly reactionary. In other cities men justly impatient with these ancient establishments organized new colleges more hospitable to experimental science. First among them were the nonsectarian University of London (later University College), which opened in 1827, and the Anglicans' counter-foundation, King's College. Laboratory instruction formed an important part of the University College curriculum from the beginning, and some of the professors were also notable for their original work. Contemporaneously men like William Thomson (later Lord Kelvin) at Glasgow were introducing similar innovations in Scotland. Finally, under threat of investigation by a Royal Commission, Oxford and Cambridge began to institute reforms in the 1850's. Progress continued slowly until the construction of the Clarendon Laboratory at Oxford and the Cavendish at Cambridge during the 1870's signified that university support for modern teaching and research had at last arrived.[47]

Modernization of medical education took somewhat longer. Through most of the century English physicians were trained at hospital schools in London and provincial centers. Here relatively good clinical teaching was available, and in London at least plenty of dead-house material for pathological anatomy. With these facilities a number of British clinicians—Addison and Bright, for example—made brilliant contributions. But once such men achieved their reputation, the demands of practice kept most of them from continuing and combining research and teaching and from establishing "schools" like those of professors in Germany. Moreover, most of the English medical colleges were essentially proprietary and therefore reluctant to establish laboratories for the basic medical sciences. Even at the best of the hospital schools, preclinical instruction was largely by lectures, except in anatomy. Only in the 1870's did some very limited facilities for practical physiology begin to appear.

Foreshadowed by the developing school of physiology at University College under William Sharpey and the appointment of Michael Foster as praelector of physiology at Trinity College, Cambridge, in 1870, the real break came with the elevation of Foster to the first chair of physiology at Cambridge in 1883 and with the nearly simultaneous appointment of John Burdon Sanderson to a similar post at Oxford. With a few exceptions, however, most of them in physiology and in the institutions with at least nominal university connections, the poverty-ridden hospital schools failed to provide adequate laboratories or financial remuneration for full-time professorships before the twentieth century.[48]

As the universities assumed the leadership in research and as science became increasingly spe-

[46] John F. Fulton and Madeline E. Stanton, *The centennial of surgical anesthesia*, 8–11, New York, Henry Schuman, 1946; Henry B. Wheatley, Sir Humphry Davy, Bart., F.R.S., *Jour. Royal Agricultural Soc. of England* **65**: 4, 1904; Beddoes, Thomas, in *Dictionary of National Biography* (2nd ed) **2**: 94–95.

[47] Turner, *op. cit.*, 69–86, 122–136.

[48] Flexner, *Medical education in Europe*, 12–15, 113–144; Puschmann, *op. cit.* (note 36), 498–534; H. Küry and H. Haig, Medical education at Oxford and Cambridge, *Ciba Symposia* **3**: 881–886, 1941; H. C. Cameron, *Mr Guy's Hospital 1726–1948*, 218–232, 278–296, London, Longmans, Green, 1954; Zachary Cope, *The history of St. Mary's Hospital Medical School or a century of medical education*, 45–46, 48, 53, 56–57, 81–82, 86, 103–108, London, William Heinemann, 1954; F. G. Parsons, *The history of St. Thomas's Hospital*, 182, London, Methuen, 1936; H. Campbell Thomson, *The story of the Middlesex Hospital Medical School*, 90–91, 103, London, John Murray, 1935; D'Arcy Power and H. J. Waring, *A short history of St. Bartholomew's Hospital 1123–1923*, 61–62, 125–131, London, The Hospital, 1923; F. J. C. Hearnshaw, *The centenary history of King's College London 1828–1928*, 295–296, 385–386, London, George C. Harrap, 1929; The Cambridge Pathological Laboratory, *British Medical Jour.*, 1889, **2**: 1182–1183; Liverpool University College: new physiological and pathological laboratories, *ibid.*, 1898, **2**: 1099–1101; Opening of the Johnston Laboratories for Medical Research in the University College, Liverpool, *Nature* **68**: 43–44, 1903; Edward Sharpey-Schafer, *History of the Physiological Society during its first fifty years 1876–1926*, 1–4, Cambridge, Univ. Press, 1927.

cialized, the relative importance of the academies declined. Particularly was this true in Germany.

> The Academy [wrote Friedrich Paulsen in 1902] is a gathering place of experts who have not much to tell each other; each man works for himself, and the personal communication of results in the meetings is often nothing more than a useless formality, yes, perhaps even more or less of a burden; while in the university master and pupil come into living, active relations with each other. It is doubtful whether any one in Germany would consider it necessary to establish such academies as separate institutions, supplied with all the equipment with which the show-loving eighteenth century fitted them out. What they now accomplish, particularly in the organization of larger scientific enterprises, could easily be done in the more modest form of learned societies which might be formed as permanent committees at the universities, and which might be authorized to admit efficient members from other circles.[49]

Nevertheless, some of the academies continued to function in part as research institutes, managing and supporting observatories, museums, botanical gardens, laboratories, and research professorships. Liebig himself left Giessen in 1852 for Munich to devote full time to his investigations in the chemistry laboratory of the Bavarian Academy of Science.[50] Moreover, the Académie des Sciences and the Royal Society, for example, were still important centers of scientific discussion and publication. By 1850 the latter had in fact changed from an eighteenth-century gentlemen's club to a truly scientific organization. Both institutions rewarded scientific achievement by prizes and the prestige of membership, and the Royal Society was entrusted through the century with increasing sums for distribution in aid of research. The national academies also organized and guided large-scale scientific undertakings, and advised their respective governments.[51]

The expansion of science during the nineteenth century nevertheless made the academies, with their limited membership and generalized scope, unable to satisfy the demand for scientific organization. Hence scientific societies, both specialist and general, both national and provincial, proliferated throughout this period. In most cases their founders were seeking to promote their respective interests primarily through discussion and publication. Commonly the societies established reference libraries. Some supported or managed museums or collections, more often for educational than for research needs and most frequently in natural history. Of particular importance was the British Association for the Advancement of Science, founded in 1831 in imitation of the nine-year-old Deutscher Naturforscher Versammlung, which with the money obtained from membership dues offered limited subventions in aid of research.[52]

In addition to the universities, academies, and societies, a number of independent establishments engaged in research or offered scientists necessary facilities. In Great Britain, for example, though the government did not finance the national academy or the universities, it did support other institutions. Some of these dated as far back as the Royal Observatory, erected in 1675. The eighteenth century saw the foundation of the British Museum 1753 and the Royal Botanic Gardens at Kew in 1760. During the nineteenth century this trend continued, notably with the Geological Survey organized in 1835 and such expeditions as the famous *Challenger* survey of 1872–1876.

Nevertheless, the efforts of men who relied largely on their own means—Charles Darwin for one—remained important. More significant for the future financing of research were those individuals who founded independent institutions for their own and others' experimental investigations. Thus John Bennet Lawes, an amateur chemist, in 1843 established at his family estate in Harpenden, England, the Rothamsted agricultural experiment station, the oldest of its kind in the world. Managed since 1889 by the Lawes Agricultural Trust, the station has expanded greatly through government aid in the last fifty years. Although directing their investigations with a view to the economic benefit of agriculture, Lawes and his co-workers made basic contributions to human as well as animal and plant nutrition. Moreover, less than a decade after Rothamsted

[49] Paulsen, *op. cit.*, 168.

[50] *Archives internationales d'histoire des sciences* **5**: 403–404, 1952; Irsay, *op. cit.* **2**: 283.

[51] Stimson, *op. cit.*, 205–227; Gaston Boissier *et al.*, *L'Institut de France*, part 2, 37–54, Paris, Librairie Renouard, 1907; George E. Hale, National academies and the progress of research, *Science* **38**: 681–698, 1913.

[52] McKie, *loc. cit.* (note 17), 138–139, 142; Mason, *op. cit.*, 355–362; *Scientific and learned societies of Great Britain, passim*, 57th ed., London, George Allen & Unwin, 1951; *Index Generalis 1954–1955, passim*, 21st year, Paris, Dunod, 1955; O. J. R. Howarth, *The British Association for the Advancement of Science: a retrospect 1831–1931*, 1–27, 146–154, Centenary [2nd] ed., London, The Association, 1931.

opened, the movement had spread to the Continent, and by 1875 there were some hundred stations. The most extensive development occurred, as one might expect, in Germany, where most of the stations were attached to universities and under strict governmental control.[53]

While the agricultural experiment stations usually centered their attention on problems of direct economic importance, another institution of contemporary origin, the marine biological laboratory, more frequently concentrated on pure research. These institutes resulted fundamentally from the changing outlook of biology itself. During the eighteenth century and the early years of the nineteenth, taxonomy was the primary interest of such leaders as Linnaeus, Lamarck, and Cuvier. This was the great era for the formation of collections and museums. During the following decades, under the influence of such gifted scientists as Johannes Müller and Claude Bernard, the study of physiology, which required laboratories, came to the fore. In addition, the publication of Darwin's *On the Origin of Species* in 1859 riveted men's attention more firmly than ever on embryology, comparative morphology, and other problems of biological growth and development. To many men it seemed that the sea with its myriad varied forms of life offered unparalleled opportunities for biological research.

Johannes Müller himself had been interested in marine studies, and his stirring discoveries at Helgoland in the 1840's made the island a favorite haunt of zoologists for years to come. Other investigators were also turning to the seaside, and in 1859 Professor J. J. Coste of the Collège de France established at Concarneau in Brittany solely for research purposes the first permanent marine biological station. The leading figure in this movement was Anton Dohrn. Born in Stettin in 1840 and started on a career as an entomologist by his father, Dohrn was inspired by Darwin's work with a passion for zoological research. After first setting up a private temporary station at Messina in 1868 to study the embryology of crabs, Dohrn secured a site from the city of Naples in 1872 for a laboratory and aquarium. Though supported in part by the German government and other outside sources, the Naples Zoological Station was a private institution. Dohrn sank his own fortune into the property, and it was subject to his sole control. Here with a small staff he was able to devote his entire energies to research. He also made available at a set fee "tables" for outside biologists who came there to pursue their own investigations. Strictly a research institute, Dohrn's station at no time engaged in teaching or in studies with a primarily economic purpose.

The Naples Zoological Station rapidly became and for long remained the foremost biological field station in the world. Following its example a number of others sprang up along the European coasts in subsequent decades. Typically they had small staffs with places for outside investigators. Most of the later ones had some connection with a university, scientific society, or government, though some were independent organizations, notably the magnificent Oceanographic Museum —a pure research institute—founded by Prince Albert of Monaco in 1899. Their functions also varied: some—perhaps half—were solely for research, whether pure or economic, some combined teaching with research, and a few were for teaching only. Altogether they constituted even before 1900 an outstanding addition to the facilities available for biological investigations.[54]

Thus by about 1880 a wide variety of facilities was available in Europe for scientific research. Laboratories, museums, botanical and zoological gardens, observatories, and similar establishments existed to serve the needs of astronomers, physicists, chemists, zoologists, botanists, and their multifold subdivisions. Most of these institutions also subserved other needs, usually educational but in some cases commercial or governmental. Some existed solely for research. Most were attached to universities or less frequently academies or societies, but a few were either entirely independent or else directly dependent on the government.

In the medical sciences specifically, nearly every teaching institution if not all had some connection

[53] *The Encyclopaedia Britannica* (14th ed.) **1**: 382–384; **19**: 571–572; Lawes, Sir John Bennet, in *Dictionary of National Biography* **22** (1st Suppl.): 951–954; Andrew Denny Rodgers, III, *Liberty Hyde Bailey: a story of American plant sciences*, 29–30, Princeton, Princeton Univ. Press, 1949; Moulton, *op. cit.*, 14.

[54] Charles A. Kofoid, *The biological stations of Europe* (U. S. Bureau of Education, Bulletin, 1910, No. 4, Whole No. 440), *passim*, Washington, Government Printing Office, 1910; Bashford Dean, The marine biological stations of Europe, *Biological Lectures Delivered at the Marine Biological Laboratory of Wood's Holl in the Summer Session of 1893*, 211–234, Boston, Ginn, 1894; Maurice Caullery, Les stations françaises de biologie marine, *Notes and Records of the Royal Society of London* **8**: 95–115, 1950; Brauer, *op. cit.* (note 29) **2**: 175–180, 578–589; Homer A. Jack, Biological field stations of the world, *Chronica Botanica* **9**: 1–73, 1945.

with a hospital where clinical-pathological research was possible. In the laboratory and experimental branches extensive facilities were generally available only in the German universities and in the other countries that had kept pace with German educational advance. Except for the anomalous Senckenberg Foundation there were no independent medical research institutes. In France, facilities for experimental research in medicine were much more limited, and in England, except for a small beginning in physiology, there were almost none.

In comparison with Europe generally, the United States suffered in respect to scientific research facilities; the gap between opportunities here and those in Germany was immeasurable. During the colonial period of American history Harvard as a Puritan institution had accepted and taught the new philosophy at a commendably early date, and a number of early New Englanders, Fellows of the Royal Society, had contributed to the advance of natural knowledge. Cotton Mather, learned in science as in other fields, is perhaps now as famous for introducing variolation and for recording the first known observation on hybrid corn, as for his witch-hunting and sermons. By the middle of the eighteenth century Philadelphia also had become a leading colonial intellectual center, comparable indeed with the provincial cities of the mother country herself. Here Benjamin Franklin made his epochal researches in electricity and here were founded British America's first important learned society, first general hospital, and first medical school.

Among the colonial scientists a small handful could obtain a living by teaching. Several of the colleges, notably Harvard, also acquired collections of instruments during the eighteenth century, primarily for demonstration purposes in the classroom but no doubt useful to research-minded professors like John Winthrop. Massachusetts helped finance Winthrop's observations of the transit of Venus in 1761 and the Pennsylvania Assembly provided similar aid in 1769. John Bartram as royal botanist received a small stipend from the Crown. These examples were exceptional, however, and by and large colonial scientists had to rely on their own means.[55]

As the nineteenth century advanced, the expanding United States experienced a rapid growth in the number of colleges. Contemporaneously the more progressive institutions began revising their curricula to take into account new fields of knowledge and new educational ideals. Among the sciences chemistry was the leader. Though included in Harvard's course in natural philosophy even before 1700, chemistry attained the dignity of a special professorship only with the introduction of medical schools. Then, first at Princeton in 1796 and soon after at Yale, colleges without medical affiliation introduced the subject. At Yale, moreover, the governing body also constructed a laboratory for Benjamin Silliman, the first professor.

Gradually in the following decades other colleges followed suit, providing their teachers with small laboratories for preparing classroom demonstrations and, if so inclined, performing their own experiments. A few institutions, beginning with Rensselaer Polytechnic Institute in 1824, the School of Applied Chemistry at Yale (forerunner of Sheffield Scientific School) in 1846, and the Lawrence Scientific School at Harvard in 1847, introduced practical laboratory courses for the students as well. Thus gradually, by paying men to teach scientific subjects, setting up chemical laboratories, and establishing mineralogical and other natural historical collections, a few of the country's colleges by the time of the Civil War were contributing towards the support of scientific research.[56]

The extent of these contributions should not be overemphasized. Harvard and Yale were far from typical, and even Yale gave its Scientific School virtually no financial backing. Rensselaer's laboratory was for elementary teaching, not research. Most colleges still paid scant attention to science, and even if they had had a desire to establish research facilities, they lacked the means. Even at such places as Cambridge, New Haven, and New York, where a few progressive educators were attempting to establish university instruc-

[55] The literature on colonial science is rapidly increasing. For an introduction see Merle Curti, *The growth of American thought*, 86–102, New York, Harper & Brothers, 1943; Whitfield J. Bell, Jr., *Early American science: needs and opportunities for study*, Williamsburg, Institute of Early American History and Culture, 1955; Theodore Hornberger, *Scientific thought in the American colleges, 1638–1800*, Austin, Univ. of Texas Press, 1945; I. Bernard Cohen, *Some early tools of American science*, 3–17, 26–53, Cambridge, Harvard Univ. Press, 1950.

[56] H. S. Van Klooster, The beginnings of laboratory instruction in chemistry in the U. S. A., *Chymia* **2**: 1–15, 1949; Hornberger, *op. cit.*, 69–74; Cohen, *op. cit.*, 66–95; Russell H. Chittenden, *History of the Sheffield Scientific School of Yale University 1846–1922* **1**: 21–74, New Haven, Yale Univ. Press, 1928.

tion and research on the German model, their efforts had little success. Neither money nor students were forthcoming. To be sure, some teachers, already under the spell of German *Wissenschaft*, showed increasing signs of devotion to scholarship. If this appeared more clearly in literary than in other fields, many of the leading American scientists by the 1840's were nevertheless college professors. But throughout the land as a whole the myriads of small denominational institutions were perforce content with a very straitened existence. To pass on a modicum of traditional learning, perhaps to inspire youth by the character of an exceptional teacher, were the only functions such colleges could expect to perform. That some of their instructors occasionally did make original contributions only illustrates how far a few individuals may go with only the most meager support.[57]

The slowly growing interest in science exhibited by the colleges between the Revolution and the Civil War was in part a reflection of a similar development outside the academic sphere. In America as in England men with an amateur or professional interest in science established other facilities to meet their needs. Prominent among them were scientific societies. Following the pioneer example of the American Philosophical Society (founded in 1743), Bostonians organized the American Academy of Arts and Sciences in 1780. During the next thirty years a number of specialized societies also appeared, most of them devoted to the application of science to the promotion of commerce, agriculture, or industry. One, the Chemical Society of Philadelphia, founded in 1792, deserves especial mention not only as one of the first organizations of its type in the world,[58] not only for the high quality of its members' work, but also for having set up its own chemical laboratory.

After about 1815 Americans were founding scientific societies, both general and specialized, at an accelerated pace. Those devoted to natural history were most common, but others were established to promote chemistry, geography, horticulture, botany, entomology, and ethnography. Of particular significance was the Association of American Geologists, formed in 1840, which resolved itself seven years later into the American Association for the Advancement of Science. Though many of these organizations were small or ephemeral, as a whole they served science like their European counterparts by popularizing it and also by providing facilities for discussion and sometimes publication. Many also established cabinets or museums of natural history. Most, perhaps, were little more than collections of curios with slight scientific value, but a few contributed significantly: America being young, many new species continued to be discovered, and taxonomy retained its primacy in American biology longer than in European. Among the most notable was the Academy of Natural Sciences of Philadelphia, founded in 1812. It acquired a fine library and extensive collections donated by some of the country's foremost naturalists. Its *Journal*, started in 1817, and *Proceedings*, which date from 1841, have contained many and varied important contributions. In Boston, the Society of Natural History, founded in 1830, established similar facilities, as did a number of others elsewhere. More unusual was the Cincinnati Astronomical Society, founded in 1842, which acquired a large observatory a few years later, one of the earliest in the United States.[59]

In addition to the colleges and societies, government also aided science to a limited extent. The states were active in organizing and financing geological surveys. The federal government in turn supported multipurpose explorations, from the Lewis and Clark venture in 1804 to the Wilkes expedition in 1838–1842 and the opening of Japan by Commodore Matthew C. Perry in 1854. Congress ignored John Quincy Adams's request for a national observatory in 1825, but one was established in the 1840's after the coast and geodetic survey work had demonstrated the need. Of even wider importance, especially for basic research, was the establishment of the Smithsonian Institution in 1846.[60]

Despite these examples, government support did not extend far before 1860. The philosophy of *laissez-faire* and governmental parsimony implicit in the Jacksonian revolt against privileges

[57] Charles F. Thwing, *A history of higher education in America*, 203–333, New York, D. Appleton, 1906; Richard J. Storr, *The beginnings of graduate education in America*, Chicago, Univ. of Chicago Press, 1953.

[58] James Kendall, Some eighteenth-century chemical societies, *Endeavour* **1**: 106–109, 1942.

[59] Ralph S. Bates, *Scientific societies in the United States*, 1–84, The Technology Press, Massachusetts Institute of Technology, New York, John Wiley & Sons, 1945.

[60] Curti, *op. cit.*, 327–333; Madge E. Pickard, Government and science in the United States: historical backgrounds, *Jour. Hist. of Medicine and Allied Sciences* **1**: 254–289, 446–481, 1946.

for the few, and the insistence of Southerners especially on strict construction of the Constitution and states' rights, did not conduce to Congressional appropriations in aid of research. Except for the Smithsonian, moreover, which was distinctly anomalous in origin and owed its character largely to the fortunate choice of Joseph Henry as first secretary, government sponsored or supported scientific research before the Civil War was very largely utilitarian—military, naval, or commercial—in character.

Mid-century Americans generally were indifferent to basic research. With the triumph of Jacksonian equalitarianism aristocratic patronage declined. The new rich arising from American industrial advances contributed little to cultural and intellectual endeavors and least of all to scientific research. Not being men of inherited wealth, learning, and leisure, they could not enjoy scientific pursuits themselves as the *virtuosi* of England once had, nor could they, as eminently "practical" men, see the value of investigations whose ultimate practicality could only be inferred from the examples of history. Support for science could not even provide the satisfactions of playing Lord or Lady Bountiful, the public recognition, and the promise of Heaven too, afforded by donations to a church or another more traditional charity.[61]

While Americans offered slight institutional aid to science generally, medicine received even less. Medicine in particular suffered from a lack of public confidence, owing primarily to therapeutic skepticism among the leaders of the profession on the one hand, and heroic treatment by bleeding and calomel by run-of-the-mill practitioners on the other. Nor, so far as the layman could see, did research at that time seem to offer much hope for improvement. Moreover, medical colleges were generally proprietary even if they had a nominal college connection, and as money-making institutions did not deserve philanthropic support. Another factor hampering both education and research was the popular aversion to dissection and the consequent difficulty of obtaining material for anatomical and pathological studies.

In a few hospitals men like William Wood Gerhard, a product of the Paris clinical school, engaged in significant clinical-pathological investigations. Such work was largely incidental, for hospitals were founded not to advance medicine but to relieve the sick poor. The number of local and state medical societies was continually increasing in the antebellum period, and the American Medical Association was formed in 1846. These groups concerned themselves chiefly with medical ethics and vain attempts to improve medical education, however, and showed little concern for research. At best they encouraged physicians to report unusual cases or make studies in geographical pathology, the latter at least being useful today as relatively objective accounts of contemporary social conditions.[62]

The few notable American accomplishments of this period were generally isolated discoveries such as new surgical operations or techniques—anesthesia, for example, or the work of Ephraim McDowell and J. Marion Sims—or, in the case of Beaumont, the fruit of genius with an unusual opportunity. Characteristically, the famous American medical men were the leading practitioners. Often they were also professors, but this was never the source of their reputation. Only rarely did one, like Joseph Leidy, who is especially known for his work in comparative anatomy and vertebrate paleontology, devote himself despite all these obstacles to systematic research. Jeffries Wyman, who was perhaps the country's ablest anatomist, was a professor of anatomy at Harvard, but in the Lawrence Scientific School; in the Medical College the genial Oliver Wendell Holmes held sway. One facility the United States had in abundance—medical journals. Unfortunately, except when excerpting European literature, they rarely had anything of significance to report.[63]

The outlook for science in America, still so limited in 1860, improved remarkably in the next two decades. In part this was due to government activities. During the Civil War, Congress established the National Academy of Sciences primarily

[61] Richard H. Shryock, American indifference to basic science during the nineteenth century, *Archives internationales d'histoire des sciences* **2**: 50–65, 1948.

[62] See, for example, early volumes of the *Transactions* of the American Medical Association.

[63] The role of medical research in American medical life is illustrated by the fact that Henry B. Shafer, in his *The American medical profession 1783 to 1850* (New York, Columbia Univ. Press, 1936), does not discuss it. But see Shafer for education, societies, etc. William F. Norwood, *Medical education in the United States before the Civil War* (Philadelphia, Univ. of Pennsylvania Press, 1944), is very thorough. On medical journals, see Myrl Ebert, The rise and development of the American medical periodical, 1797–1850, *Bull. Medical Library Assoc.* **40**: 243–276, 1952; Oliver Wendell Holmes, Report of the Committee on Medical Literature, American Medical Association, *Transactions* **1**: 249–288, 1848.

as an advisory body for the federal government but also for the advancement of scientific research. In succeeding years, however, until the World Wars of the twentieth century, it developed chiefly as an honorific organization, recognizing original scientific work of outstanding merit by election to its company.[64]

The federal government has in fact supported scientific research more concretely by hiring its own scientists. While the Coast and Geodetic Survey already had an established reputation in certain of the physical sciences before 1860, the biological sciences began to receive more attention during and after the Civil War. Research centered especially in the Department of Agriculture. Foreshadowed by the Agricultural Division of the Patent Office established in 1840, the independent department came into existence in 1862, the same year that Congress passed the Homestead Act and the Morrill land-grant act for the support of agricultural and mechanical colleges. Though most of its scientific achievements have occurred since 1880, the Department's able investigators even before that date had undertaken research in botany, entomology, veterinary medicine, and the chemistry of foodstuffs. Some of the Department's work was later to prove of prime importance for medical science as well as of economic benefit to farmer and consumer alike.[65]

Far more significant for the future of science in the United States was the birth of genuine university education during the 1870's. The most successful of the prewar efforts to transform the American college—widely recognized as the equivalent of the German gymnasium—into a university had been at Yale, where the Department of Philosophy and the Arts, established in 1847 for graduate students and for undergraduates in the school of applied chemistry, began to offer the Ph.D. degree in 1860. The work was on a genuinely high level—so wrote Harvard's president in 1869—but the graduate enrollment was small. By 1870 Yale had granted only seventeen Ph.D.'s (more than half in science), which made hardly a ripple in the increasing stream of Americans seeking university education in Germany.[66]

In 1869 Charles W. Eliot became president of Harvard and, besides reconstructing the law and medical schools, proceeded to revolutionize American collegiate instruction. Prior to his advent Harvard had introduced a very limited number of elective courses. Eliot, considering all cultural subjects to be equally valuable for disciplining the mind, greatly expanded the students' freedom of choice and within a few years rendered it effective for almost the entire curriculum. A firm supporter of liberty, Eliot believed that any student worth worrying about could best judge for himself what courses to pursue. He also recognized that the elective system was the only practical way to get new subjects into the curriculum. A notable enrichment of offerings resulted, not only through the introduction of fields with a limited appeal, but also in modern history, the social sciences, English literature, modern languages, the fine arts, and philosophy.

By enabling students to concentrate, moreover, the elective system forced teachers to dig more deeply into their subjects that they might present advanced courses. Establishment of the Graduate Department (later the Graduate School of Arts and Sciences) in 1872 offering earned M.A. and Ph.D. degrees further reinforced this stimulus to research. Then too, as the teaching of advanced courses became possible, wealthy supporters of one or another field of knowledge outside the traditional curriculum could more readily be persuaded to endow chairs or provide buildings and equipment. Thus under Eliot, Harvard grew from a college where some professors happened to engage in research into a modern university with continually enlarging laboratories, libraries, museums, and other facilities for the pursuit of original investigations.[67]

While it might be difficult to say which of Eliot's reforms did the most for Harvard, his greatest contribution to higher education in America was unquestionably the elective system. In the development of graduate instruction the influence of the Johns Hopkins University, which

[64] Bates, *op. cit.*, 77–84, 128–131.

[65] T. Swann Harding, *Two blades of grass: a history of scientific development in the U. S. Department of Agriculture* (Norman, Univ. of Oklahoma Press, 1947), is an excellent account; for the period before 1880, see pp. 7–32.

[66] Storr, *op. cit.*, 53–58; Chittenden, *op. cit.* 1: 39–42, 48, 60; *Catalogue of the officers and graduates of Yale University in New Haven Connecticut 1701–1924*, 453, New Haven, The University, 1924; Charles F. Thwing, *The American and the German university*, 42–43, New York, Macmillan, 1928.

[67] Samuel E. Morison, *Three centuries of Harvard 1636–1936*, 334–361, Cambridge, Harvard Univ. Press, 1936; *idem*, ed., *The development of Harvard University since the inauguration of President Eliot 1869–1929, passim*, Cambridge, Harvard Univ. Press, 1930; Thwing, *op. cit.* (note 57), 418–419, 432–445.

was incorporated in 1867 and opened in 1876, was paramount. Its first president, Daniel Coit Gilman, and a sympathetic board of trustees from the beginning emphasized research. Believing that both teaching and research could reach the highest level only in conjunction and only in circumstances of full academic freedom, Gilman carefully selected for the faculty men who not only were investigators themselves but who also gave promise of instilling in their students their own love of research. While emphasizing men rather than buildings, Hopkins was also careful to provide them with the necessary working facilities and means of publication. Thus a picked group of graduate students and fellows, working in close, informal relations in the seminar or laboratory with men who were themselves advancing knowledge, received an education in research. Leaving Hopkins for professorial posts elsewhere, they spread the gospel throughout the land.[68] As Eliot himself said in 1902, Gilman had created at Hopkins "a school of graduate studies which not only has been in itself a strong and potent school, but which has lifted every other university in the country in its departments of arts and sciences." [69]

Thus during the 1870's and 1880's Yale, Harvard, Johns Hopkins, and a few other American institutions, following the examples set in Germany and other European nations, were spreading the spirit of laboratory research through the United States at an increasing rate. In botany, for example, only a few small and more or less private laboratories, such as Asa Gray's at Harvard, had existed prior to 1870, but by 1885 a dozen or more creditable establishments existed at American colleges and universities. Harvard, which had the best, set up in 1872 for advanced students, also had the Bussey Institution, founded in 1871 as an agricultural school, where William G. Farlow and others had pursued research in cryptogamic botany and phytopathology; a botanical garden, founded in 1805 but completely renovated in the 1870's; the Gray and Farlow herbariums; and the Arnold Arboretum.[70]

While Harvard under Asa Gray held the leadership in botany, John P. Norton, professor of agricultural chemistry at Yale, and his successor Samuel W. Johnson were foremost in the promotion of laboratory research in this branch of science. Following Johnson's report on European stations, and largely through his influence, Connecticut founded in 1875 the first of the American state agricultural experiment stations and placed it under the direction of Wilbur O. Atwater, professor of chemistry at Wesleyan and a former student of Johnson. In 1877 the station moved to New Haven and Johnson became director. As one might expect, its research related primarily to the applications of chemistry to agriculture. North Carolina also established a station at Chapel Hill in 1877, and Cornell organized another in 1879. As the movement spread, agitation for federal action developed, leading in 1887 to the Hatch Act with its provisions for federal aid. By the end of 1888, every state had an agricultural experiment station. Most were closely connected with a university—usually the land-grant institution—but supported independently. Some thus approached the status of independent research institutes.[71]

More clearly independent than the agricultural experiment stations were the early marine biological laboratories, which also owed much to European examples. Louis Agassiz, the professor of zoology at Harvard, founded the first in America, except for private ones, in 1873 on Penikese Island in Buzzard's Bay. Supported by a New York merchant and known after him as the (John) Anderson School of Natural History, it was planned primarily for summertime teaching but also for encouraging research. Because of Agassiz's death in 1873 and subsequent financial difficulties, the Anderson School lasted only two years. In 1875, however, the United States Fish Commission, founded in 1871 at the urging of Spencer F. Baird, then assistant secretary of the Smithsonian Institution, fitted up a laboratory at Woods Hole. Though work there was interrupted the following year, the Commission returned to this site in 1882. Baird, who sought a national center for biological research, obtained financial support from interested individuals and universities, and was able to invite outside in-

[68] W. Carson Ryan, *Studies in early graduate education: the Johns Hopkins, Clark University, the University of Chicago* (Carnegie Foundation for the Advancement of Teaching, Bulletin No. 30), 15–46, New York, 1939.

[69] Quoted in *ibid.*, 3.

[70] Andrew Denny Rodgers, III, *American botany 1873–1892: decades of transition*, 198–201, 227–229, Princeton, Princton Univ. Press, 1944; Morison, *Development of Harvard*, 338–370, 508–510.

[71] Chittenden, *op. cit.* **1**: 199–204; Rodgers, *L. H. Bailey*, 29–46; *idem*, *American botany*, 245–246; A. C. True, Origin and development of agricultural experiment stations in the United States, *Report of the Commissioner of Agriculture 1888*, 541–545, Washington, Government Printing Office, 1889.

vestigators to use the laboratory's facilities. In 1885 a permanent station was established, which has since accommodated a varying number of scientific workers.

Meanwhile Alpheus Hyatt, Curator of the Boston Society of Natural History, had started a small laboratory school in Annisquam in 1880, which he organized more formally the following year with the aid of the Society and of the Boston Women's Educational Association. Carried on successfully through 1886, Hyatt's school led to the formation of the Woods Hole Marine Biological Laboratory in 1888, an independent institution for both teaching and research supported by private benefactions and staffed by faculty members of several universities and colleges. The forerunner of a long line of similar stations established since 1890, Woods Hole soon became one of the nation's most influential centers of pure biological research.[72]

Through the development of fundamental biological knowledge, through insight gained from studies of animal and plant pathology, as well as through the resulting improvements in the food supply, botanical, agricultural, and marine biological research institutions have ultimately had great value for human health. Yet research lagged in sciences more specifically related to medicine. Interested individuals and governments were willing to support chemical and agricultural research as the results quickly demonstrated its economic worth. The usefulness of fundamental discoveries in anatomy, physiology, or even pathology was often less obvious to the lay mind, which judged medicine only in so far as it could prevent or cure disease. Despite the achievements of medical research since 1800, the doctor of 1880, as Sir Luke Fildes's painting suggests (and the mortality statistics demonstrate), could still do little more for a child with diphtheria than wait. While this was better than the bleeding and purging of an earlier era, the significance of the advance was hardly apparent to the anxious parent.

Moreover, medical schools in the United States, though increasingly inadequate in comparison with the rising standards of medical science, were still generally proprietary. As such they did not deserve or obtain public endowment. Deriving their income solely from students' fees, these schools could not support full-time salaries and medical research. Under the existing competitive conditions they could spare little for laboratories and equipment if they expected to stay in business, nor could they afford to be particular about whom they admitted. Even so basic a course as anatomy suffered from lack of material, and even the best schools asked no more of their entering students than a high school education. Most Americans—indeed most American physicians—failed to realize the growing importance of an adequate scientific basis for the practice of medicine. Those who did, and who had the means, went to Germany, where most American degrees in medicine, according to Theodor Puschmann, were "placed in the same category as those amiable but meaningless distinctions which are conferred on people dancing the cotillon." [73]

Even Puschmann, however, recognized that there were some signs of light. One was a special course of premedical studies introduced at the Sheffield Scientific School in 1869. Probably the first in America, it was built on the principle that medicine should rest on a foundation of scientific knowledge. Perhaps even more important, considering the character of contemporary medical schools, was the program's training in scientific method. The first two graduates, in 1872, were Thomas Hubbard Russell, later professor of materia medica at Yale, and T. M. Prudden, later professor of pathology at the College of Physicians and Surgeons. After Sheffield reorganized and broadened the course in 1874, it attracted an increasing number of students. Medical schools soon recognized its superiority, a judgment borne out by the excellent records of its graduates.[74]

The Sheffield School also set up in 1874 the earliest American laboratory for instruction in physiological chemistry, under the direction of Russell H. Chittenden, who was still an undergraduate. After a trip to Germany in 1878–1879 for the advanced training he could not get in this country, Chittenden returned to develop in a few years an active center of research and teaching for college and graduate students, the first in this field in America.[75]

While Yale led the way in premedical studies and in biochemistry, Harvard took the first defini-

[72] Ralph W. Dexter, The Annisquam sea-side laboratory of Alpheus Hyatt (1838–1902), *Scientific Monthly* **74**: 112–116, 1952; Frank R. Lillie, *The Woods Hole Marine Biological Laboratory*, 15–46, Chicago, Univ. of Chicago Press, 1944; Robert T. Young, *Biology in America*, 68–74, Boston, R. G. Badger, 1922.

[73] Puschmann, *op. cit* (note 36), 535.

[74] Chittenden, *op. cit.* **1**: 164–165, 239–243.

[75] *Idem, The development of physiological chemistry in the United States*, 15–40, New York, Chemical Catalog Company, 1930.

tive steps toward improving the medical schools themselves. Until 1869, when President Eliot took the unprecedented step of attending a meeting of the faculty, the medical school was virtually an independent proprietary institution. Led by Dr. Henry J. Bigelow, who had no use for science and believed that physicians were born, not made, the conservatives fought every forward step, but Eliot and a band of young progressives turned the school over, in Holmes's words, "like a flapjack." Harvard took over financial control in 1870, established stiffer entrance requirements and written examinations for the degree, and instituted the first required three-year graded course in the history of American medical education.

Eliot also separated anatomy from physiology in 1871, and, leaving Holmes in charge of the former, appointed to the latter a young student of Carl Ludwig, Henry Pickering Bowditch. The first full-time professor in the school, Bowditch found two small rooms in the garret of the old North Grove Street building where he could set up the laboratory equipment he had brought back from Germany. Some years earlier John Call Dalton, a student of Claude Bernard and a pioneer in this country in using experimental demonstrations for teaching physiology, had set up a physiological laboratory at the College of Physicians and Surgeons, but it was essentially private and he did not attract a school of followers. Bowditch, on the other hand, opened his laboratory to advanced students and thus founded the first university physiological institute in America. Here he not only carried on his own investigations, but trained and inspired a significant number of the coming leaders in American medical research. In 1876 Henry Newell Martin, a student of Michael Foster and Thomas H. Huxley, came to Johns Hopkins from Cambridge, England, to establish in the university biological laboratory the second American center for physiological research.

Though the immediate result of Eliot's reforms was a drop in enrollment, the Harvard Medical School soon attracted an increasing number of abler students. The old North Grove Street building became inadequate but the university had no money for a new one. The public rarely contributed to medical education so long as the professors had organized for profit, and it took time to convince prospective donors that at Harvard this was no longer the case. Eventually, however, the university raised enough money to construct a new and, as it was thought, fully adequate building, which opened in 1883. The same year the Corporation appointed Bowditch dean. For the first time the post went to a laboratory scientist rather than a leading local practitioner.[76]

Despite these efforts, support for scientific investigations in the United States in 1880 was still extremely limited. In chemistry alone can it be said that opportunities for advanced work and research in reasonably well appointed laboratories under competent directors were no longer rare. The plant sciences boasted a number of agricultural-college laboratories, a few state experiment stations, and the nascent program of the United States Department of Agriculture. For zoologists and especially for paleontologists there were several museums and societies as well as a few active university centers. In the medical sciences physiological chemistry was represented by Chittenden at Yale, while Bowditch and Martin headed the only laboratories devoted to experimental physiology. Similar centers in embryology, pathology, pharmacology, or hygiene were nonexistent. It is hardly surprising that during the 1880's the number of American students in German universities reached a new peak.[77]

Among the reasons for the increasing flow of Americans to Europe was the desire of young medical men from the United States to learn more about the dramatic new discoveries of bacteriology. One need only recall a few dates to suggest its great impact at this time. In 1876 Robert Koch demonstrated the complete life cycle of the anthrax bacillus, rigorously proving for the first time that a specific bacterium caused a disease that affects humans. In 1878 Koch published his great work on the etiology of wound infections. In 1880 Pasteur discovered a method of immunizing against chicken cholera, Alphonse Laveran discovered the malaria parasite, and C. J. Eberth the typhoid bacillus. In 1881 Pasteur produced his anthrax vaccine and Koch invented the solid-culture method for isolating microorganisms. He announced the discovery of the tubercle bacillus in 1882, and of the cholera bacillus in 1883. The following year Georg Gaffky obtained a pure cul-

[76] Morison, *Development of Harvard*, 555–563; Morison, *Three centuries of Harvard*, 338–340; Walter J. Meek, The beginnings of American physiology, *Annals of Medical Hist.* **10**: 120–125, 1928; George Rosen, Carl Ludwig and his American students, *Bull. Inst. Hist. of Medicine* **4**: 619–626, 1936; H. Sewall, The beginnings of physiological research in America, *Science*, n.s. **58**: 187–195, 1923.

[77] Thwing, *op. cit.* (note 66), 42.

ture of typhoid bacillus and demonstrated its causal relationship to typhoid fever, while Friedrich Löffler accomplished the same feat for diphtheria. In 1885 Pasteur introduced his treatment for rabies. In 1888 Emile Roux and Alexandre Yersin discovered the diphtheria toxin, and André Chantemesse and Georges Widal introduced their experimental typhoid vaccine. In 1889 Shibasaburo Kitasato obtained pure cultures of the tetanus bacillus, which Arthur Nicolaier had first described five years earlier. In 1890 Kitasato and Emil von Behring published their pioneer paper on diphtheria and tetanus antitoxins and their immunizing powers. Truly this was a decade of startling discoveries.

Koch had published his first three important works while still a district physician in Wollstein, working in a small laboratory in his own home. Then in 1879 Ferdinand Cohn, professor at the Breslau University institute of botany, where Koch had first demonstrated his findings on anthrax, obtained a position for him as municipal physician in Breslau. Discovering that the job paid too little and left even less time for research, Koch went back after three months to the country town. Much as the villagers rejoiced at his return, Wollstein was too small for his genius, and in 1880 he was called to a post in Berlin at the Imperial Health Office (Kaiserliche Gesundheitsamt). Though founded in 1876 primarily for administrative duties, the Health Office soon experienced a need for research facilities and in 1879 set up laboratories for chemistry and hygiene. Far more important was the bacteriology laboratory instituted for Koch the following year. Here he not only introduced the solid-culture method, which more than any other single technical development of this era made the subsequent discoveries in bacteriology possible, but also, with his co-workers Gaffky and Löffler, demonstrated the causative organisms of tuberculosis, cholera, typhoid fever, and diphtheria.

The work of Koch's bacteriological laboratory at the Imperial Health Office was extremely important for both its immediate practical value in protecting the public health and the paths which it opened to future discoveries. It was also significant as an institutional development. Independent research institutes of various types already existed for physics, astronomy, chemistry, botany, marine biology, and zoology. Now for the first time a laboratory was organized and its staff paid an adequate salary on a full-time basis solely for medical research. To be sure men from all over the world came there to learn the new techniques, and Koch did offer a course in cholera diagnosis at the Health Office. Since these teaching duties were never burdensome, it is perhaps possible to consider this laboratory the first modern nonuniversity medical research institute. That it should have originated in Germany under government auspices is fitting, in view of the support for science which German states had for decades provided through the universities and the nation's advanced medical-social legislation. But it was also a fortuitous method of giving the necessary opportunity to a young man of genius for whom there was at the moment no suitable opening in the educational hierarchy. As such it constitutes simply another variation in the evolution of institutional forms.

Koch left the Health Office in 1885 for a new post as professor of hygiene in the University of Berlin in an institute created especially for him. Under his successors the Health Office continued to be an important center of productive medical research. Here, for example, P. T. Uhlenhuth did his work in serology, and Fritz Schaudinn in 1905 discovered the spirochete of syphilis.[78]

The influence of a few professors and the wisdom of a few officials were largely responsible for the German government's assistance to Koch. Widespread popular support for medical research first became manifest after Pasteur's dramatic demonstration of his preventive treatment for rabies. Having first tried the method in July, 1885, Pasteur announced to the Academy of Medicine on 1 March 1886 a record of three hundred and fifty cases with one failure. As Emile Roux later noted, this discovery "did more for the popularity of Pasteur than all his previous labors."[79] Acting upon a plan already conceived by Pasteur, the Academy of Sciences opened an international subscription for an establishment to be known as the Pasteur Institute, partly as a dispensary for

[78] William W. Ford, The life and work of Robert Koch, *Bull. Johns Hopkins Hospital* **22**: 419–422, 1911; Brauer, *op. cit.* **1**: 320–323, 326–332; B. Möllers, Sechzig Jahre Reichsgesundheitsamt, *Arbeiten aus dem Reichsgesundheitsamte* **70**: 383–399, 1936; F. A. Weber, Das Reichsgesundheitsamt: seine geschichtliche Entwicklung und Organisation sowie seine Bedeutung für die Volksgesundheit in den 50 Jahren seines Bestehens, *Klinische Wochenschrift* **5**: 1305–1308, 1926; L. Haendel, Reichsgesundheitsamt und wissenschaftliche Forschung, *ibid.* **5**: 1377–1380, 1926.

[79] The medical work of Pasteur, trans. by Erwin F. Smith, *Scientific Monthly* **21**: 383, 1925.

persons bitten by rabid animals, but also as a center for research on contagious and virulent diseases. A veritable wave of popular enthusiasm swept France and extended to other nations. Rich and poor joined in giving more than two and a half million francs, sufficient to provide an endowment of one million francs and extensive laboratories. Government subventions and the sale of vaccines against anthrax, chicken cholera, and swine erysipelas later added to the Institute's income.

On 14 November 1888 the President of France and other dignitaries ceremoniously inaugurated the new Institute. An autonomous corporation, it was managed under statutes approved by the French government by a Director, a Council of twelve (which elected the Director), and an Assembly (which elected the Council). Besides private quarters for Pasteur, the building contained space for departments of rabies treatment and vaccine research under J. J. Grancher and Charles Chamberland; of general bacteriology under Emile Duclaux, who was especially interested in the biochemistry of micro-organisms; and of technical bacteriology under Roux, who centered his attention on medical aspects. The latter two engaged in both research and teaching, Duclaux transferring his Sorbonne course in biochemistry to the Pasteur Institute, and Roux giving instruction in the techniques of bacteriology. In addition a group of small research laboratories under the general supervision of Elie Metchnikoff was available for individual scientific investigators.

Pasteur entered the Institute "a man," in his own words, "vanquished by time." But his disciples and their students carried on and expanded his work, so that the laboratories which had seemed so magnificent in 1888 soon proved insufficient. Roux's announcement in 1894 of his practical success in the production and use of diphtheria antitoxin in a large number of cases stimulated a Paris journal to open a new public subscription, which enabled the Institute to enlarge greatly its facilities for producing the serum. Other substantial gifts from private philanthropists also began to come in. One made possible the 120-bed Pasteur Hospital, which, opening in 1900, afforded facilities for clinical investigations. From the beginning all patients were admitted free. Another benefactor provided large biochemical laboratories for Duclaux especially outfitted for studying agricultural and industrial applications of microbiology. Other donations later enabled

FIG. 1. Pasteur Institute: View from Rue Dutot. Courtesy New York Academy of Medicine.

the Institute to take up research in protozoology, tropical microbiology, entomology, mycology, and plant physiology and pathology, as well as tuberculosis, cancer, and syphilis.

While the scientific reputation of the Pasteur Institute is such that its accomplishments need no exposition, its importance in institutional history should be emphasized. The laboratories of the German Health Office may be considered the first modern nonuniversity medical research institute, but the Pasteur Institute was the first that was an independent corporation. Its facilities and staff were also much larger, and the fields of investigation embraced in its program more varied. The Pasteur Institute was also a center for treating rabies, manufacturing vaccines, and teaching biochemistry and microbiology, but these interests subserved its primary function, the advancement of scientific biological knowledge. Finally, because of its size, its success, and its fame, the Pasteur Institute, rather than the German Health Office, became the prototype of similar institutes throughout the world.[80]

Its influence is obvious in the origin of the next important medical research institute founded. Following Pasteur's example, H.R.H. Prince Alexander Petrovich Oldenburg set up a station in St. Petersburg to give the preventive treatment for rabies. Then with Pasteur's advice he founded

[80] France, Ministère du travail, de l'hygiène, de l'assistance et de la prévoyance sociales, *Livre d'or de la commémoration nationale du centenaire de la naissance de Pasteur célébrée du 24 au 31 Mai 1923*, 307–354, Paris, Imprimerie nationale, 1928; Vallery-Radot, *op. cit.*, 427–429, 440–444; L'Institut Pasteur, *Annales de l'Institut Pasteur* **3**: 1–14, 1889.

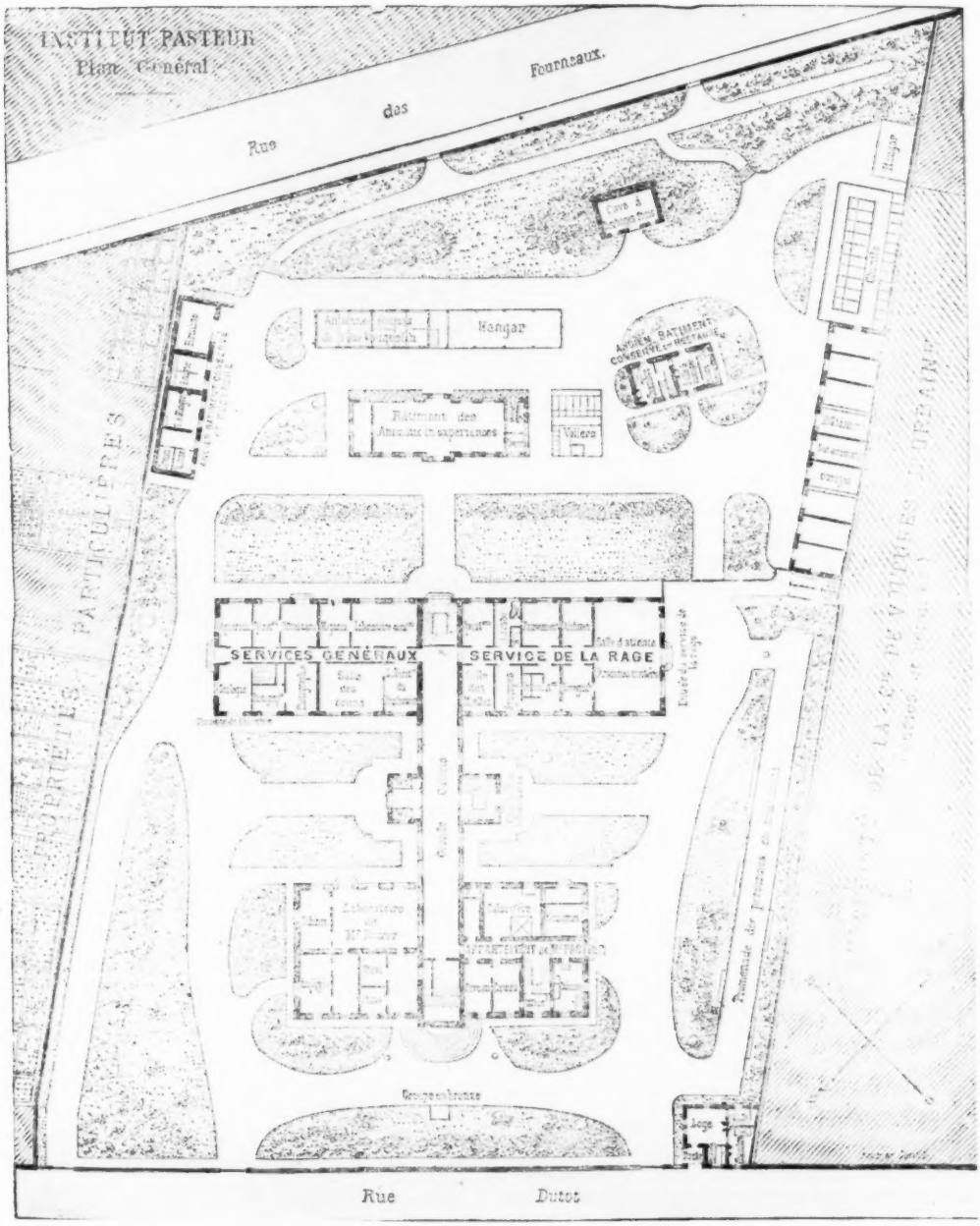


FIG. 2. Pasteur Institute: Ground plan. *Annales de l'Institut Pasteur* **3**: 8–9, 1889.

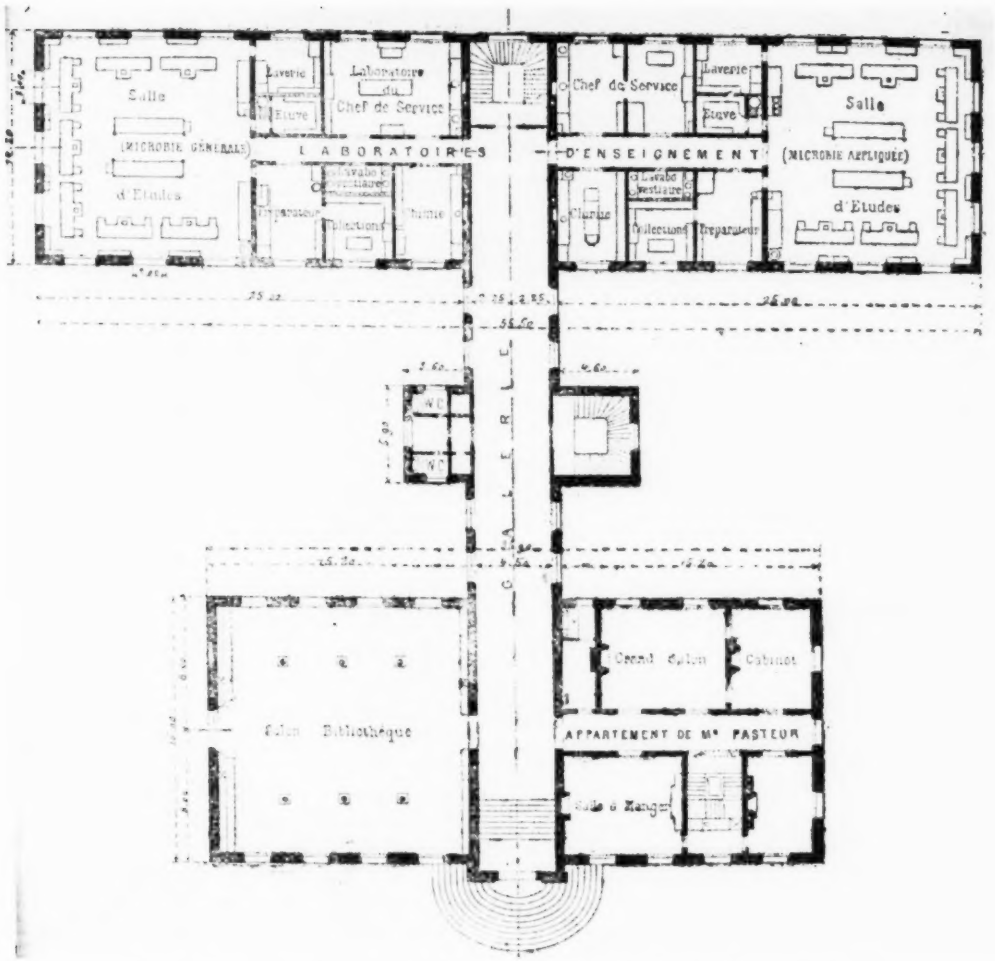
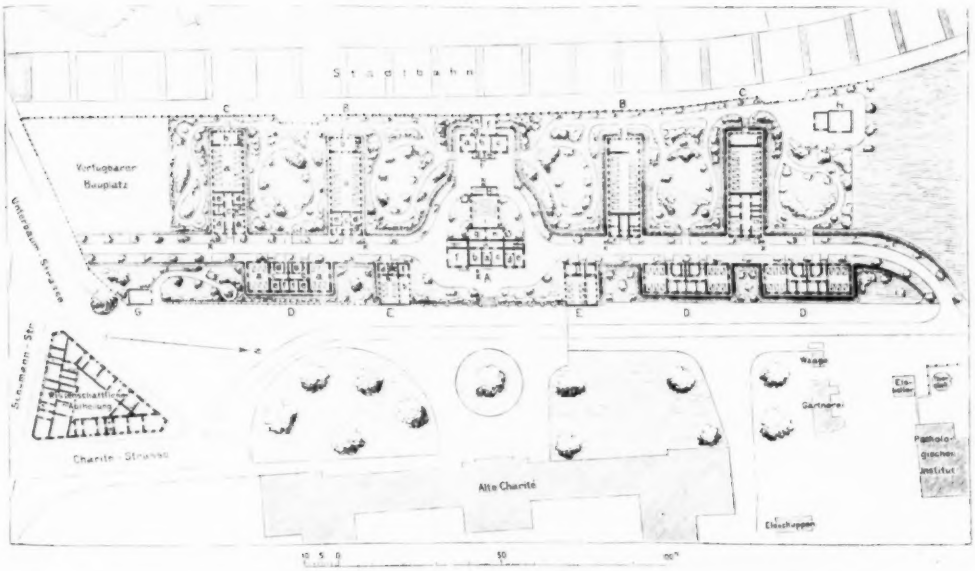


FIG. 3. Pasteur Institute: Second floor plan. *Annales de l'Institut Pasteur* **3**: 5, 1889.

on a large site in the same city the Russian Institute for Experimental Medicine. Opening in December, 1890, it contained fully equipped laboratories for physiology, biochemistry, bacteriology, pathology, and veterinary medicine, in addition to the rabies dispensary. The establishment also included about a dozen isolated villas for experimental study of different diseases and a small hospital. Besides paying the research expenses and salaries of the staff, the Institute provided living quarters for the director and his principal assistants and an inexpensive but excellent restaurant. Like the Pasteur Institute it published its own *Archives des Sciences Biologiques*.

The main function of the Russian Institute was research in pure biological science and in the development and testing of new drugs and other methods for the treatment and prevention of disease. From the beginning it was staffed by a number of brilliant men, including M. von Nencki, S. N. Vinogradski, and N. Anitchkov. Most famous of all was I. P. Pavlov, the first head of the department of physiology. Throughout his years at the Institute, where he spent most of his



A Verwaltungsgebäude.
a Flur, b Wartezimmer für das Publicum, c Wartezimmer für die Kranken, d Abfertigungszimmer, e Schreiberei, f Speisenausgabe, g Zimmer des Docenten, h Vorbereitungszimmer, i Hörsaal.
B, C, D Krankenbaracken.
a Krankensaal, b Tageraum, c Flur, d Bad, e Wärterzimmer, f Theeküche, g Abort, h Gerätheraum.
E Wohnbaracken für Wartepersonal.
a Schlafsaal, b Tageraum, c Flur, d Bad, f Theeküche, g Abort.
F Desinfections- und Sectionsgebäude.
a Wäschesortirraum, b Desinfectionsraum, c Raum für gereinigte Wäsche, d Desinfectionsraum für Speisereste, e Bad, f Secirraum, g Flur, h Leichenraum.
G Kohlenschuppen.
H Eiskeller und Kohlenschuppen.
Hydranten.

FIG. 4. Koch Institute: Ground plan. *Berliner Klinische Wochenschrift* **28**: 903, 1891.

productive scientific career, until 1924, Pavlov was also a professor at the Military-Medical Academy, actively engaged in teaching. Many of the workers in his laboratory at the Institute were students, often medical practitioners who had come back for the M.D. degree. Like other investigators under Pavlov's direction, they worked under close supervision on problems definitely assigned and explicitly outlined by the master: Pavlov's laboratory was not the place for a young man with his own ideas to try his wings.

After founding the Institute, Oldenburg turned it over to the Russian government, whence came thereafter its financial support. It remained independent of other governmental departments and some years later the state bestowed the title Imperial, adding not only to the Institute's prestige but also to its income. After the Revolution it became a branch of the All-Union Institute of Experimental Medicine.[81]

[81] The Imperial Russian Institute of Experimental Medicine, *British Medical Journal*, 1891, **1**: 36; Fiftieth anniversary of the Institute of Experimental Medicine in Leningrad, *Science* **92**: 573–574, 1940; B. P. Babkin, *Pavlov: a biography*, 67–71, 115–116, Chicago, Univ. of Chicago Press, 1949.

In England, as in Russia, the example of the Pasteur Institute led to the founding of the first modern medical research institute. In a typically English manner, a self-constituted committee of citizens early in 1889 appealed for funds as a contribution to the Pasteur Institute for having treated more than two hundred persons from Britain free. The committee did not advocate an English station for the rabies treatment, preferring to press for muzzling and quarantine legislation, but, distressed by the paucity of medical research facilities in their own country, they decided to seek money for an institute in all other respects similar to the Pasteur. Though hampered and delayed by anti-vivisectionists, the committee was finally able to obtain a charter in June, 1891, for the British

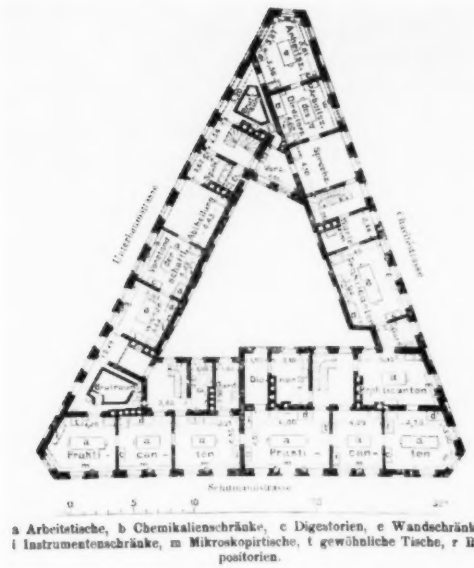

a Arbeitstische, b Chemikalienschränke, c Digestorien, e Wandschränke, i Instrumentenschränke, m Mikroskopirtische, t gewöhnliche Tische, r Repositorien.

FIG. 5. Koch Institute: Laboratory building. *Berliner Klinische Wochenschrift* **28**: 926, 1891.

Institute of Preventive Medicine, the first chairman being Sir Joseph Lister. From 1897 to 1903 it was known as the Jenner Institute of Preventive Medicine, taking thereafter the name of Lister.

Lacking government support and hard pressed for funds, the Institute succeeded in raising a capital of about fifty thousand pounds from its original appeal. Premises were obtained by amalgamation with the College of State Medicine, an institution founded in 1886 for laboratory instruction in public health, and in 1893 the British Institute was able to begin work. Among the earliest objects of its attention was the new diphtheria antitoxin, the Institute being the first to produce it in England. As in France, its dramatic success enabled the Institute to conduct a second appeal for funds in order to set up an experimental farm for the study and production of this and other sera. The Institute's financial position continued precarious until 1900, however, when a gift of two hundred and fifty thousand pounds from Lord Iveagh made possible more satisfactory arrangements for a permanent scientific staff.

The number of appointees has never been more than thirty, but the Institute has welcomed qualified guests wishing to pursue investigations in its fields. These have always included bacteriology, experimental pathology, and biochemistry, but as the need or occasion has arisen, other divisions—protozoology, entomology, statistics, and nutrition being examples—have from time to time been set up. Though unconnected with the government, the Institute also acted for many years as a diagnostic public health laboratory for London.[82]

Among the reasons for the founding of the French, Russian, and British institutes was the relative paucity of medical research facilities, especially in bacteriology, in these countries. Though this motive did not apply in Germany, with its numerous university laboratories, the example set by France and Russia nevertheless aroused a demand for a similar establishment in the Fatherland. Moreover, Koch was anxious to give up his teaching duties in order to devote his full time to research. His announcement of the discovery of tuberculin afforded the final impetus. In August, 1891, the Institute for Infectious Diseases (Institut für Infectionskrankheiten), founded for and designed by the great bacteriologist, opened in Berlin. It included two main divisions, a hospital of 108 beds and a laboratory building for bacteriological and chemical research. Typically, for Germany, the financial support came from the government.[83]

Under Koch's direction the new laboratories, like his university institute earlier, immediately became a scientific mecca. Among the outstanding investigators that the master gathered about him was Shibasaburo Kitasato, co-discoverer with von Behring of diphtheria and tetanus antitoxin, who had been with Koch since 1885. Kitasato returned to his native Japan in 1892, where with the aid of Yukichi Fukusawa, a noted philanthropist, he established his own small private Institute for Infectious Diseases. Soon thereafter the newly established Japanese public health association took over the general management of the laboratory, appointing Kitasato director. In 1893 the Imperial Diet also began providing financial support.

The Institute comprised a scientific and a clinical department. The latter maintained a 50-bed

[82] Harriette Chick, The Lister Institute of Preventive Medicine, *Endeavour* **8**: 106–111, 1949; R. J. Godlee, *Lord Lister*, 491–501, London, Macmillan, 1917; The history of the Royal Institute of Public Health, *Jour. State Medicine* **32**: 9–10, 1924.

[83] Richard Bochalli, *Robert Koch: der Schöpfer der modernen Bakteriologie*, 103–104, Stuttgart, Wissenschaftliche Verlagsgesellschaft, 1954; George Meyer, Das Koch'sche Institut für Infectionskrankheiten zu Berlin, *Berliner Klinische Wochenschrift* **28**: 902–904, 926–927, 1891.

hospital for contagious diseases and a dispensary. The former included a didactic branch, which offered a three-months postgraduate course in practical bacteriology, and a laboratory for original research, where Kitasato and his assistants worked on tsutsugamuchi disease, plague, and the production of various sera. Particularly notable were Kitasato's discovery of the plague bacillus in 1894, contemporaneously with Yersin, and Kiyoshi Shiga's discovery in 1898 of the dysentery bacillus that bears his name.

In 1899 the Imperial Home Department assumed control of the Institute, leaving Kitasato in charge. Increased governmental support further strengthened the organization, and it continued as the leading medical research foundation in Japan. In 1914, however, the government without consulting Kitasato placed the Institute under the Ministry of Education, thereby subordinating it to Tokyo University. Because of this shift, of which he disapproved, and the political reasons that lay behind it, Kitasato resigned with his entire staff and established a new Kitasato Institute for Infectious Diseases, a nonprofit corporation deriving its income from endowment and the sale of biologicals. This foundation also continued to operate a hospital and to offer postgraduate courses.[84]

Another of Koch's assistants at the Institute for Infectious Diseases was Paul Ehrlich, whose contributions to the production and standardization of Behring's diphtheria antitoxin made possible its practical application. To insure the quality of this preparation, which was rapidly being introduced into medical practice, the German government set up a control station in Koch's Institute in February, 1895. The great demand for this and other sera and the number of research problems connected with the growing science of immunology soon rendered this arrangement inadequate. The government therefore established a new State Institute for the Investigation and Control of Sera (Staatliches Institut für Serumforschung und Serumprüfung) in 1896 in Steglitz, a suburb of Berlin. Appointed director of the new institute, Ehrlich soon made valuable contributions to the further development of serum therapy and the improvement of testing methods.

Ehrlich soon saw the need for a more extensive establishment and especially for a hospital connection. Fortunately the Director of the Prussian Ministry of Educational and Medical Affairs, who was noted for his understanding and encouragement of research, recognized that Ehrlich deserved larger opportunities. No hospitals were available in Berlin, but the mayor of Frankfurt a. M., home of the Senckenberg Foundation, proved receptive. With his active aid and a financial contribution from the city the state established there a new Institute for Experimental Therapy (Institut für Experimentelle Therapie) in 1899 with Ehrlich as director.

Ehrlich's Institute had a variety of functions. As the successor to the Steglitz establishment, one section tested all the sera and vaccines controlled by the state. Another branch undertook diagnostic and other bacteriological work for the local health authorities, hospitals, and physicians. Finally, under the direct leadership of Ehrlich stood the experimental division, which was devoted solely to research, primarily in immunology. And soon the Institute was enlarged. A private gift in 1902, supplemented by a contribution from the state, made possible a division for cancer research. Two years later Frau Franziska Speyer founded in memory of her husband the Georg Speyer House Chemotherapeutic Research Institute (Chemotherapeutische Forschungsinstitut Georg Speyer-Haus) as an adjunct to the existing establishments.[85]

While the laboratories of the German Imperial Health Office, and the Pasteur, Russian, Lister, Koch, Kitasato, and Ehrlich institutes, were probably the most prominent nonuniversity medical research foundations prior to the present century, a large number of other similar if smaller institutions were also established in the same period. Some were even older than the Pasteur. The National Museum of Brazil, for example, which originated in the eighteenth century and installed laboratories for physics and chemistry in the 1820's, set up an experimental physiology labora-

[84] A. Nakagawa, Progress of Professor Kitasato's Institute for Infectious Diseases at Tokio, *Science*, n.s. **6**: 313–315, 1897; Twenty-five years of the Kitasato Institute, *Kitasato Archives* **17** (no. 3): i-iv, 1940; Mikinosuke Miyajima, *Teacher and pupil*, 1–4, 20–35, Tokyo, 1935; *The history of the Kitasato Institute for Infectious Diseases*, 1–3, Tokyo, Kitasato Institute, [1950?].

[85] Martha Marquardt, *Paul Ehrlich*, 29–48, London, William Heinemann, 1949; Wilhelm Kolle, *Das Staatsinstitut für experimentelle Therapie und das Chemotherapeutische Forschungsinstitut "Georg Speyer-Haus" in Frankfurt a. M.* (Arbeiten aus dem Staatsinstitut für experimentelle Therapie und dem Georg Speyer-Hause zu Frankfurt a. M., Heft 16, 2. Auflage), 6–12, 20–23, Jena, Gustav Fischer, 1926.

tory in 1878, primarily for Professor Louis Couty's studies on curare and other poisons.[86] In Denmark, J. C. Jacobsen, head of the Carlsberg brewery, established the Carlsberg Laboratory in 1875 for investigating malting, brewing, fermenting, and similar processes. Further strengthened the following year by the new Carlsberg Foundation, the laboratory became in fact a pure research institute in basic physiological and biochemical problems. The Foundation itself, which was designed to nourish many branches of learning, has also supported scientific research in other ways.[87]

Most of these other institutes, however, stemmed like the Pasteur from the development of bacteriology and especially its dramatic therapeutic successes. A number, in fact, took the Pasteur name. Albert Calmette from the Paris Institute established the first of the so-called Instituts Pasteur d'Outre-Mer at Saigon, Indochina, in 1890 as a laboratory for smallpox and rabies vaccination. Here he began work on snake venoms, and in 1893 Yersin, working from the Saigon Institute, discovered contemporaneously with Kitasato the plague bacillus. In 1895 Yersin established the second Indochinese Institut Pasteur at Nhatrang, primarily to make the new plague serum developed in Paris. In Africa, the Institut Pasteur de Tunis, founded in 1893, later became, under Charles Nicolle, an important center of research, as did the Institut Pasteur d'Algérie, founded in 1894, and the Institut Pasteur in Dakar, descendant of a bacteriological laboratory first set up in 1896.[88]

Similarly, in British Asia the Haffkine Institute in Bombay started in 1896 as a plague research laboratory. In 1900 the Malayan government established the Kuala Lumpur Institute for Medical Research, which centered its attention on malaria and beriberi. In the Near East, Turkey established an Imperial Bacteriological Institute at Constantinople in 1893 under the direction of Maurice Nicolle, a student of Pasteur's disciple Roux.[89]

In Latin America, the Mexican Institute of Hygiene originated in 1895 as the National Bacteriological Institute, a section of the Anatomy-Pathology Museum, for the production of sera and research. The state government of São Paulo, Brazil, established a Bacteriological Institute in 1889 for investigating yellow fever and other infectious diseases. Ten years later the same authority also set up the Butantan Institute primarily for manufacturing plague serum. It later became famous especially for the work of Vital Brazil on snake venoms. In the same year, 1899, the city of Rio de Janeiro also founded an establishment for producing plague serum. Taken over by the central government the following year as the Federal Institute of Serum Therapy, in 1908 it became in honor of its first director the now world famous Instituto Oswaldo Cruz.[90]

Other nations of Europe also took part in this movement. In Switzerland, for example, the Serum and Vaccination Institute (Schweizerisches Serum- und Impfinstitut), founded in Bern in 1880, produced bacteriological therapeutic preparations under state control and investigated related problems. In Italy, the Istituto Sieroterapico of Milan, founded in 1894 under the direction of Gaetano Negri, Luigi Mangiagalli, and Camillo Golgi, engaged in both practical work—bacteriological diagnosis, immunization, and the production of sera—and general microbiological research. In France, the Institut Pasteur de Lille, founded by public subscription in 1894 and placed under the direction of Calmette, followed on a smaller scale the path of its namesake.[91]

Great Britain, meanwhile, was turning to other sources for the support of research facilities. One was the medical society: in 1887 the Royal College of Physicians of Edinburgh founded its Research Laboratory and placed it under the direction of a full-time paid superintendent. Open to members of the society and to approved outsiders, it had facilities for studies in chemistry, histology, bacteriology, and experimental physiology. Most of the investigators in early years were clinical men

[86] Leonidio Ribeiro, *Brazilian medical contributions*, 7–9, Rio de Janeiro, José Olympio, 1939.

[87] Brauer, *op. cit.* (note 29) **2**: 652–655.

[88] France, Ministère du travail, *op. cit.*, 354–360; Institut Pasteur: cinquantième anniversaire de sa fondation, *Annales de l'Institut Pasteur* **62**: 707–713, 1939.

[89] *The world of learning*, 447, 5th ed., London, Europa, 1954; The Pathological Institute at Kwala Lumpor, *British Medical Jour.*, 1900, **2**: 1202; J. W. Field *et al.*, *The Institute for Medical Research 1900–1950* (Studies from the Institute for Medical Research, Federation of Malaya, No. 25), 37–40, Kuala Lumpur, The Government Press, 1951.

[90] Ribeiro, *op. cit.*, 5–6, 13–23; Scientific institutions in Latin America, *Boletin de la Oficina Sanitaria Panamericana* **19**: 44–46, 1940; **20**: 35–36, 246, 1941; Nosso patrimonio scientifico: o Instituto Oswaldo Cruz, *Sciencia Medica: Revista Brasileira de Medicina e Sciencias Affins* **4**: 41–50, 1926.

[91] Brauer, *op. cit.* **2**: 576–577, 675; France, Ministère du travail, *op. cit.*, 363.

working part time. It was not used for teaching.[92] Another British innovation, which has proved more productive in the twentieth century, was the industrial medical research laboratory. In 1894 Mr. Henry Wellcome, of Burroughs Wellcome & Company, founded the Wellcome Physiological Research Laboratories for investigations chiefly in immunology. Though much of the work was related to the business of the firm, the laboratories were a distinct organization under separate direction.[93]

In the United States, too, the advances in medicine and primarily in bacteriology were at last demonstrating to the general public the practical value of medical research and thereby inducing increased support. Other universities were following Yale and Johns Hopkins in the initiation of graduate instruction, and other medical schools were following Harvard in setting up laboratories. The editor of the *Boston Medical and Surgical Journal*, though he recognized that the country still had a long way to go, reported in 1884 that this movement was one of the most hopeful indications in current medical education.[94]

Locally the editor might have pointed to Harvard's new building, opened the previous year. In New York, a gift from Andrew Carnegie in 1884 enabled the Bellevue Hospital Medical College, which had previously provided the young William Welch with a small room for his microscopic investigations, to erect a new research and teaching laboratory in pathology and bacteriology, the first of its kind in the United States. Two years later the medical department of New York University opened the similar Loomis Laboratory. By 1893 New York City boasted three medical school laboratories, each with better facilities than the entire country had provided but twenty years before.[95]

By that time other centers were also establishing laboratories for original investigations. The University of Michigan, for example, set up a hygiene laboratory in 1889, as did the University of Pennsylvania. Three years later gifts from Henry Charles Lea, the medical publisher, and others enabled Pennsylvania to inaugurate the first American university institute of hygiene.[96] It was Johns Hopkins, however, that seized the leadership in American medical education during these years. Here the same spirit of freedom and emphasis on research that had formed the character of graduate education at the university since 1876 also permeated the Johns Hopkins Hospital and the Medical School, which opened in 1889 and 1893 respectively. Both, furthermore, were well endowed and well equipped. The number of leading American medical scientists in the succeeding decades who had been students, interns, or residents at Hopkins is eloquent testimony to its influence.[97]

At this same period certain state and local health departments were also establishing laboratories. The earliest were for chemical investigations, like those set up by the New York Metropolitan Board of Health in 1866 and the Louisiana State Board of Health in 1870.[98] Though largely concerned with more or less routine administration, a few of them also gave some time to original work. Of much greater importance were those founded for bacteriological studies. Notable among these was the Lawrence, Massachusetts, Experiment Station, set up in 1886 by the state board of health, which carried out fundamental research in water supply and sewage disposal. Two years later the Providence health department also established a sanitary bacteriological laboratory for investigating similar problems.[99]

Somewhat later than the sanitary laboratory but of equal if not greater significance was the diagnostic laboratory. In 1887 Hermann M.

[92] John Ritchie, *History of the Laboratory of the Royal College of Physicians of Edinburgh*, 1-22, Edinburgh, Royal College of Physicians, 1953.

[93] Walter Dowson, *The Wellcome Physiological Research Laboratories, founded 1894*, 9, London, [1903?].

[94] The relation of laboratories to medical science and medical education, *Boston Medical and Surgical Jour.* **110**: 233-234, 1884.

[95] Claude E. Heaton, *A historical sketch of New York University College of Medicine 1841-1941*, 18, 20, New York, New York Univ. 1941; W. H. Thomson, Modern experimental medicine, *Trans. New York Academy of Medicine*, ser. 2, **10**: 531, 1893.

[96] Simon Flexner and James Thomas Flexner, *William Henry Welch and the heroic age of American medicine*, 342n, New York, Viking Press, 1941; S. G. Dixon, Notes on the Hygienic Public Health Laboratory, *University Medical Magazine* **2**: 152-155, 1889-1890; S. W. Mitchell, Address on opening of the Institute of Hygiene of the University of Pennsylvania, *ibid.* **4**: 401-406, 1891-1892.

[97] Richard H. Shryock, *The unique influence of the Johns Hopkins University on American medicine*, Copenhagen, Ejnar Munksgaard, 1953.

[98] New York State, Metropolitan Board of Health, *Annual Report* **1**: Appendix, 17, 1866; Letter from Dr. Ben Freedman, Louisiana State Department of Health, 18 Jan. 1956.

[99] Wilson G. Smillie, *Public health: its promise for the future*, 346, 350, 390-391, New York, Macmillan, 1955; C.-E. A. Winslow, *Man and epidemics*, 21, 97-98, Princeton, Princeton Univ. Press, 1952.

Biggs, T. Mitchell Prudden, and a Marine Hospital Service Surgeon diagnosed a fatal case of alleged cholera morbus on an immigrant vessel as true Asiatic cholera by isolating the bacillus, thus forestalling a serious possibility of the introduction of the disease into New York. In 1892 a similar situation enabled the Commissioner of Health to obtain long sought funds from the city government for a bacteriological laboratory. Once established, it proved useful in many ways. In particular, the Department of Health began offering regular bacteriological diagnosis of diphtheria in 1893, and the following year it started producing the new diphtheria antitoxin. Astutely, Biggs secured a law that authorized the Department to produce, distribute, and sell the serum, which not only made it available at a controlled and reasonable price but also provided funds for further investigations. Appointed director of the laboratory in 1893, William H. Park, in the words of C.-E. A. Winslow,

> made this institution not only the outstanding example of practical applications of bacteriology to administrative public health but a center of notable scientific research. In the bacteriology and serology of diphtheria, in the study of scarlet fever, tuberculosis, meningitis and poliomyelitis, in milk bacteriology and the control of infant diarrhea, Park and his associates made contributions of the first order.[100]

Moreover, New York City set the example for a large number of state and municipal bacteriological laboratories founded elsewhere within the next few years. While their work related primarily to practical problems of health administration, many have also contributed importantly to the advancement of medical science.[101]

Along with local and state authorities the central government was also taking part in extending support to medical research. During the 1880's the most prominent example of federal science was perhaps the United States Geological Survey, which John Wesley Powell sought to forge into a far-ranging institution for bringing the benefits of science to bear in the development of the nation.[102] So powerful indeed did the Geological Survey become that it aroused violent opposition. Representative Hilary Herbert of Alabama noted with alarm in 1892 that the United States spent more for the promotion of science than any other nation in the world. If geology as Powell conceived it, he asked, was a fit concern of the federal government, why should not also be physics, chemistry, and biology?[103]

Temporarily Powell's enemies had their way. But already the Alabama Congressman's rhetorical question was finding an answer that would have appalled its author. The growing program of scientific research in the Department of Agriculture is a case in point. Its results for medicine have been in many instances extremely beneficial, although in a sense incidental. As an example one need only cite the work of Theobald Smith on Texas cattle fever. More directly concerned with medical science was the Army Medical Corps. Several of America's earliest outstanding bacteriologists, George Miller Sternberg being one, were army officers and worked with army support. The Armed Forces Institute of Pathology is the lineal descendant of the Army Medical Museum, founded in 1862, which soon became more than a mere repository. Within the walls of the Museum building erected in 1887 were the bacteriological laboratories used by Walter Reed.[104] Even the United States Marine Hospital Service, long noted chiefly for its intimate relation to the pork barrel, was gradually moving toward its future transformation into the Public Health Service. In 1887 a Marine Hospital Service surgeon established a small research laboratory in the Staten Island Marine Hospital. Moved to Washington in 1892, it eventually became the Hygienic Laboratory, pursuant to an act of 1902 that charged the Service with regulating interstate sale of antitoxins and similar preparations.[105]

[100] *Idem, The conquest of epidemic disease,* 340, Princeton, Princeton Univ. Press, 1943. See also, *idem, The life of Hermann M. Biggs, M.D., D.Sc., LL.D., physician and statesman of the public health,* 91–116, Philadelphia, Lea & Febinger, 1929; Wade W. Oliver, *The man who lived for tomorrow: a biography of William Hallock Park, M.D., passim,* New York, E. P. Dutton, 1941.

[101] S. W. Abbott, State laboratories as aids to sanitary work, *Jour. Medicine and Science* (Portland) **7**: 71–79, 1900–1901; W. H. Welch, Relations of laboratories to public health, *Public Health: Papers and Reports of the Amer. Public Health Assoc.* **25**: 460–465, 1899; Ben Freedman, The first state board of health laboratories in the United States, *Public Health Reports* **69**: 867–875, 1954.

[102] Wallace Stegner, *Beyond the hundredth meridian: John Wesley Powell and the second opening of the West, passim,* Boston, Houghton Mifflin, 1954.

[103] *Ibid.,* 341.

[104] Edgar E. Hume, *Victories of army medicine: scientific accomplishments of the medical department of the United States Army,* Philadelphia, J. B. Lippincott, 1943.

[105] Smillie, *op. cit.,* 466–467.

Laboratory research in medicine was also beginning to receive support late in the nineteenth century from independent institutions. In 1884, for example, Edward L. Trudeau opened his Adirondack Cottage Sanitarium, which he designed in part for both clinical and laboratory research on tuberculosis. The laboratory, first set up in Trudeau's home, was transferred to a separate building erected for the purpose in 1894 through the generosity of Mr. George C. Cooper.[106] In 1890 Samuel G. Dixon, who had established the first hygienic laboratory at the University of Pennsylvania, resigned his post there to have more time for original work and set up a new bacteriological laboratory under the auspices of the Academy of Natural Sciences of Philadelphia. In 1892 the Academy appointed him Professor of Histology and Microscopic Technology, which was primarily a research post, but apparently Dixon himself provided the chief financial support for his laboratory.[107]

Again, in 1892 the Wistar Institute of Anatomy and Biology was chartered to preserve the anatomical teaching collection of the old Wistar Museum, to add to the collection material and equipment for more advanced study of anatomy, and to prosecute researches in anatomy and other biological subjects. The University of Pennsylvania presented the Museum and the site, while General Isaac J. Wistar provided the building and endowment. Under the first two directors until 1904, the staff of the Institute concentrated on improving the museum rather than on research, but its laboratories and collections were occasionally used by guests for their investigations.[108]

Thus by 1900 there were in the Americas, Asia, and Europe a number of institutions devoted to research in the medical and other biological sciences. Many of them also engaged in teaching. In the universities this was the primary function and lay behind the development of laboratories and similar facilities. By 1900 most educational thinkers agreed that at the graduate level research was an indispensable adjunct to teaching. Other institutions—the Pasteur, Russian, Kitasato, and Lister Institutes among them—were initially founded primarily for research but also gave instruction in certain specialized subjects or had on their staffs men who taught regularly in outside schools.

A second major group of medical research institutes also performed governmental functions, chiefly the protection of the public health through diagnosis or treatment of disease, or the production or regulation of antitoxin and similar products. The Pasteur Institute was also in this group, as were the Ehrlich Institute, the Research Laboratories of the New York City Department of Health, and a large number of other government organizations.

Finally there were the pure research institutes that did not engage in organized teaching and had no regular government function. Several of these existed in the physical and biological sciences, notably those supported by the long established national scientific academies and the marine biological stations. In the medical sciences, however, only the Koch Institute, of the larger establishments, could be placed in this category, and even this was in a very real sense a vital postgraduate educational institution.

These various institutional forms were the result of centuries of growth. In the enthusiasm of the seventeenth century for universal science, experimental medicine had first found support through the academies' provisions for anatomical and physiological investigations. In the eighteenth century science was beginning to become too specialized for this approach, but a few pioneer universities started fostering scientific research seriously. The great flowering of university research in Germany in the nineteenth century brought in its train such spectacularly successful results that the independent institute was revived for specific branches of science, including the medical. Thus by 1900 the world afforded numerous facilities for medical investigations, most of them in Europe. The tremendous expansion of medical research in the twentieth century has been firmly based on these foundations.

[106] E. L. Trudeau, The history of the tuberculosis work at Saranac Lake, *Medical News* **83**: 769–780, 1903.

[107] S. G. Dixon, The development of Bacillus tuberculosis, *Proc. Acad. Nat. Sci. Philadelphia*, 1890, 438–440; Letter from M. E. Phillips, Editor, Academy of Natural Sciences of Philadelphia, 24 Jan. 1956.

[108] Organization and work of the Wistar Institute, The Wistar Institute of Anatomy and Biology, *Bulletin* No. 5: 3–4, Philadelphia, 1916; Twentieth anniversary of the organization of the advisory board of the Wistar Institute of Anatomy and Biology, Wistar Institute, *Bulletin* No. 6: 27–33, Philadelphia, 1925.

THE MAGNETICALLY SUPPORTED EQUILIBRIUM ULTRACENTRIFUGE*

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(*Read November 10, 1955*)

THE ultracentrifuge methods for measuring molecular weights originally were introduced by Svedberg and his students over thirty years ago, and have been used extensively by them in their classical experiments on the characterization of proteins (1). At the present time, as a result of the development of good high speed ultracentrifuges, some of which are commercially available, the methods are widely used in studies especially of high molecular weight compounds both in this country and abroad. In addition to the determination of molecular weights, the ultracentrifuge is of great use in the purification of many different substances (1, 2). It is fortunate that the centrifugal fields necessary to purify a substance or to measure its molecular weight are far too small to deactivate appreciably even the most unstable substances so far studied.

Two principal methods of determining molecular weights by the ultracentrifuge method are in use (1). The first known as the velocity of sedimentation method requires a relatively high centrifugal field and a centrifuging time of a few hours, while the second, known as the equilibrium method, requires a much smaller centrifugal field but a centrifuging time of several days, or even weeks. In the past, the velocity of sedimentation method has been more widely employed where the molecular weights are large enough to give an appreciable rate of sedimentation. The principal reason for the limited use of the equilibrium method in the past has been the great difficulty of maintaining the rotor speed and rotor temperature of the ultracentrifuge sufficiently constant for the long times required for equilibrium to take place. On the other hand the equilibrium method is more reliable because it is based directly upon thermodynamic theory instead of Stoke's Law, as is the case with the velocity of sedimentation method. In addition, it gives absolute values of the molecular weights directly. Furthermore, with the same rotor speed, the equilibrium method may be used for much smaller molecular mass measurements and does not require a knowledge of the diffusion constants.

The purpose of this paper is to describe some improvements in the equilibrium ultracentrifuge technique which we have under way at the University of Virginia (3, 4, 5). If M_e is the molecular weight of a mono-disperse substance, then by the equilibrium method

$$M_e = \frac{2RT \log_e c_1/c_2}{4\pi^2 N^2 (1 - Vd)(r_1^2 - r_2^2)}$$

where c_1 and c_2 are the concentrations at the radial distances r_1 and r_2 respectively, V is the partial specific volume, d is the density of the solution, N the number of revolutions per second of the rotor and T is the absolute temperature. The above relation holds strictly only for an ideal dilute incompressible solution so that when the solution is non-ideal and not dilute, it must be corrected (1). Professor John W. Williams and his students (5) especially have shown how this may be done. However, in all cases the three quantities to be measured while the centrifuge is spinning are the rotor speed, rotor temperature, and the concentration of the solution at the various radial distances in the cell. The other factors such as V and d are determined from measurements made outside the centrifuge cell.

Figure 1 is a schematic diagram of the apparatus. The rotor is freely suspended inside a non-magnetic vacuum chamber by means of the axial magnetic field of the solenoid. The rotor is accelerated to operating speed by means of an air turbine situated below the vacuum chamber. The turbine is connected with the rotor by a small-diameter flexible steel shaft which passes through vacuum tight low vapor pressure oil glands. When the desired operating speed is reached, the shaft is disengaged from the rotor by means of an air piston arrangement located below the turbine and the rotor coasts freely during the course of the sedimentation measurements. Figure 2 shows the drive system in detail. It might be noted that when the shaft is pulled out of the rotor the air

* Supported by the N.S.F. and Navy Bu. Ord.

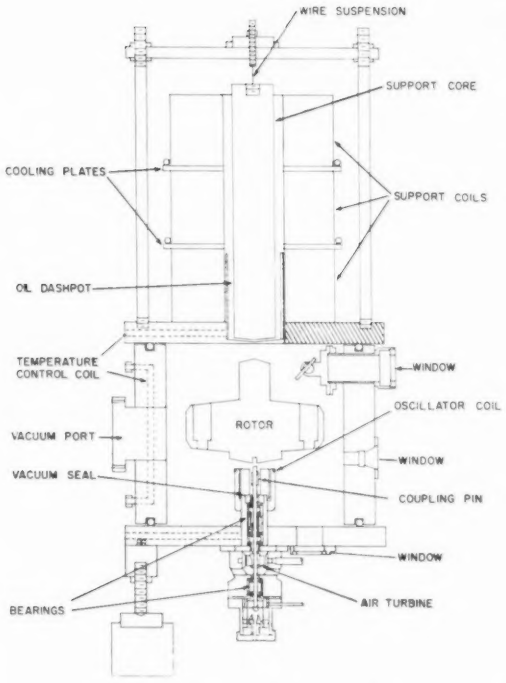

FIG. 1. Diagram of ultracentrifuge.

turbine is stopped and the shaft clamped down in such a way that the base of the coupling pin completely seals the vacuum chamber.

Two types of rotors for equilibrium measurements are in use. The first which weighs about 10 lbs. is made of duralumin with a steel core while the second which weighs about 30 lbs. was machined from a single piece of high-strength alloy steel. Each rotor has four 2.4 cm. channels drilled parallel to the axis of rotation with their centers 65 mm. from the axis. These channels carry the centrifuge cells and counterbalances. The maximum diameter of each rotor is 9.4 cm. and the moments of inertia are such as to insure stable rotation about the vertical axis shown in figure 1. The cylindrical brass vacuum chamber is 22.2 cm. high, 23 cm. i.d. with a wall thickness of 1.76 cm. The top and bottom plates of the vacuum chamber are made of brass and are 30 cm. in diameter and 1.9 cm. thick. Neoprene O rings provide the vacuum seal between the end plates and the cylinder. Channels which carry a liquid at constant temperature are provided in both the cylinder and the end plates. The temperature of the chamber is held constant to about 0.03° C. by circulating water from a thermostat bath flowing through the cooling channels. A radial slit is cut in the upper plate as indicated by the shading in figure 1, and then filled with a low vapor pressure thermoplastic or a wax. The purpose of this slit is to suppress possible eddy currents in the upper plate which might interfere with the support. Four glass windows 4.15 cm. in diameter and 1.02 cm. thick of good optical quality provide two different light paths through the rotor. The vacuum chamber is evacuated through a 7.6 cm. metal tube by means of an oil diffusion pump and a "Megavac" fore pump. The pressure in the chamber is determined by an ionization gauge.

The solenoid or support coil which suspends the rotor magnetically is situated above the vacuum chamber and consists of 36,000 turns of No. 22 insulated copper wire. The core of the solenoid is a soft iron rod 2.4 cm. in diameter and 30 cm.

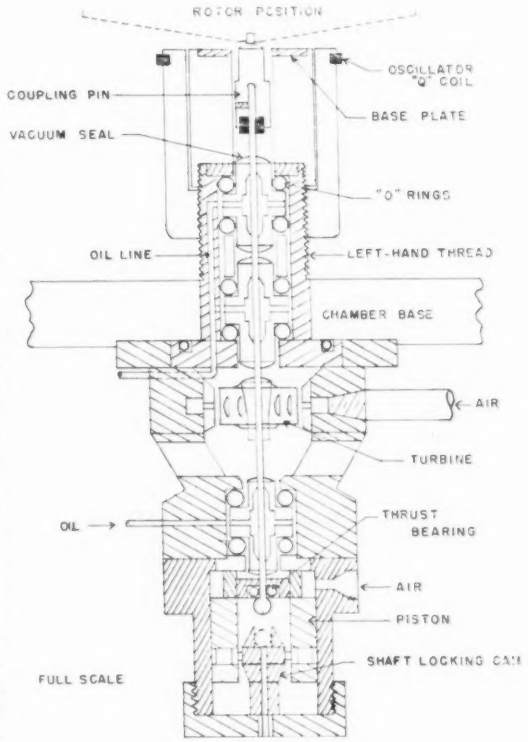

FIG. 2. Air drive system.

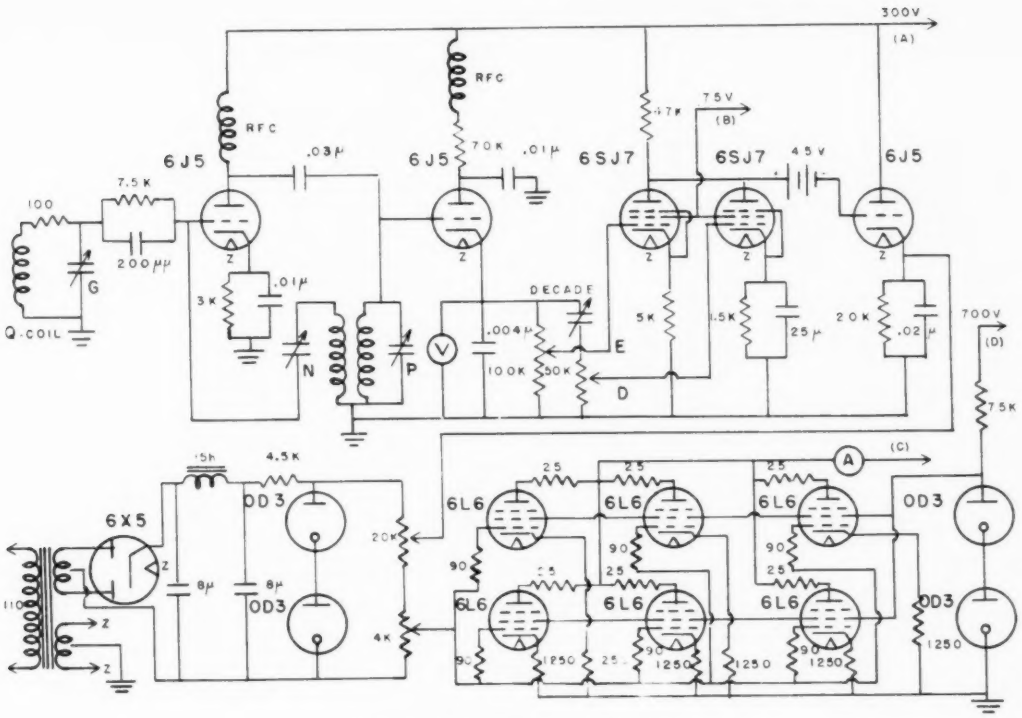

FIG. 3. Magnetic suspension circuit.

long. It is suspended by a 0.0623 cm. piano wire. The lower end of the core is immersed in an oil (No. 30 motor oil) dash pot and is about 0.15 cm. above the top of the vacuum chamber. The purpose of this pendulum-like core is to damp out any horizontal motion of the rotor that might develop.

The servo circuit which regulates the current in the support solenoid is shown in figure 3. The principle of this circuit has been described in detail previously (3, 4) so only a very brief outline of its function will be given here. A small sensing or Q-coil situated below the rotor is in the grid circuit of a tuned-grid tuned-plate oscillator which has a frequency of several megacycles per second. If the rotor moves downward, the impedance of the sensing coil is changed in such a way as to increase the current through the solenoid which in turn raises the rotor. If the rotor moves upward the signal from the sensing coil reduces the current in the solenoid and the rotor moves back down. By inserting so called "anti hunt" into the servo circuit the rotor is automatically held in a given vertical position without any motion which can be observed by a microscope focused on the rotor surface. Since the rotor is suspended freely inside a vacuum chamber by an axial magnetic field the rotor friction should be very small. In practice, the 30 lb. rotor when coasting freely at 300 rps with the vacuum chamber pressure below 10^{-6} mm. of Hg loses the order of one rps in three days. The rotor speed is determined by a photomultiplier tube placed between M_2 and I_2 in figure 4, in a light beam which is interrupted once each revolution of the rotor. The signal from the photomultiplier is amplified and compared on an oscilloscope screen with an amplified signal from the National Bureau of Standards radio station WWV or a signal generator calibrated and continuously monitored by WWV. The rotor speed is adjusted to be approximately equal to one of the broadcast frequencies of WWV or one of its multiples or submultiples. This gives a precision in the rotor speed of at least one part

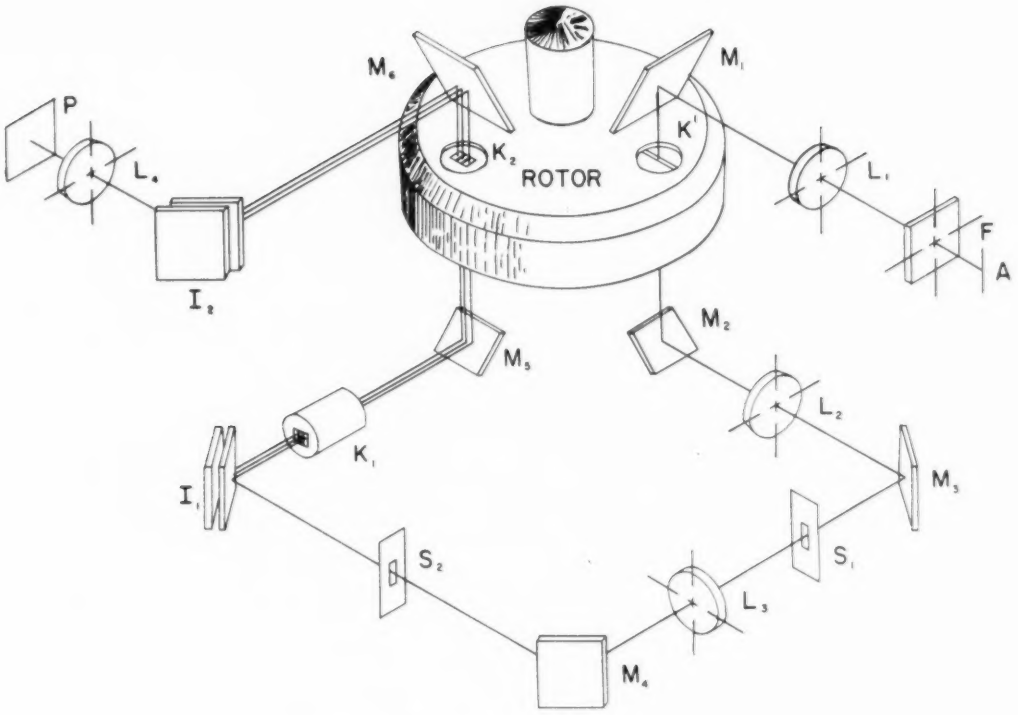

FIG. 4. Interferometer and light chopper.

in 10^6. The high precision in the rotor speed together with the fact that the rotor temperature can be held constant at a known temperature to the order of one part in 10^4 makes it highly desirable to increase the reliability with which the concentration in the centrifuge cell as a function of the rotor radius can be measured.

The concentration of the sedimenting substance in the centrifuge cell is usually determined by measuring the index of refraction of the solution while the centrifuge is spinning. The relation between the concentration and the refractive index n is easily determined outside the centrifuge with high precision by standard methods. Figure 4 shows a combination light chopper and Jamin type interferometer used for determining the refractive index in the centrifuge cell at various rotor radii. Light from a high intensity mercury arc not shown is focused on the slit A. It is then made monochromatic by the filter F and brought to focus on the slit K' by the lens L_1. K' is a radial slit in the centrifuge rotor. The light is next focused by L_2 on S_1 and made parallel by the lens L_3. S_2 is a diaphragm which limits the width of the beam to prevent overlapping in the centrifuge cells K_1 and K_2. The interferometer plates I_1 are properly silvered to split the incident light beam into three beams of very roughly the same intensity which pass on through K_1 and K_2. The interferometer plates I_2 recombine the three beams and the lens L_4 brings the cell K_2 to focus on the photographic plate P. I_1 and I_2 are each made of a pair of optically flat glass plates with their silvered surfaces facing each other. The front plate is silvered to give from 25 to 35 per cent reflection while the rear plate is full silvered. If each pair of interferometer plates is accurately parallel the interferometer fringes will be at infinity. However, if one of the plates in I_2 is rotated or inclined with respect to the other by the proper small angle, the fringes appear in sharp focus on the photographic plate superposed on the images of the centrifuge cell K_2. Since there are three beams passing through K_2, at least three

separate images of K_2 with superposed interferometer fringes appear in sharp focus side by side on the photographic plate P. The first image on P arises from the combination of the first and second light beams counting from the right, while the second or middle image of K_2 arises from the combination of the second and third beams superposed upon an image produced by the first and second beams. The third image is due to the combination of the second and third beams. The first and third image each has a single set of intense fringes while the second has two sets of intense fringes. Before sedimentation starts the two sets of fringes in the middle image usually are displaced with respect to each other by an amount corresponding to the change in phase at reflection.

The centrifuge cell K_2 is sector shaped with its sides accurately aligned along the rotor radius. It is divided into two sector shaped compartments or cells by a liquid tight radial partition. The smaller compartment subtends an angle of approximately 2° while other subtends about 4° at the axis of the rotor. K_2 is sealed by one crystal quartz window on the top and a second on the bottom. Its construction is similar to one previously described in detail.[4] K_1 is identical with K_2 and is used as a compensator.

The solution containing the substance to be analyzed is placed in the smaller compartment while the solvent is placed in the larger compartment of K_2 to exactly the same radial depth. K_1 is then filled in the same way except that the solvent fills the smaller and the solution the larger compartment. The cell K_2 is next sealed and precisely aligned in the centrifuge rotor. The vacuum chamber is evacuated to at least 10^{-5} mm. Hg pressure and the rotor with the drive shaft attached is magnetically supported. The rotor is turned to the position shown in figure 4 by rotating the air turbine by hand. Next the interferometer is adjusted so that the first beam on the right passes through the compartment in K_2 containing the solution while the second and third beams pass side by side through the larger compartment in K_2 containing the solvent. K_1 is placed in the beam so that the first beam passes through the small compartment containing the solvent and the second and third pass through the larger compartment containing the solution. As sedimentation takes place in the solution, the fringes formed by the first and second beams shift their position on the photographic plate P. The change in concentration ΔC due to a shift of one fringe is $\Delta C = \Delta n/k = \lambda/kh$ where n is the refractive index, λ is the wave length of the light, k is the specific index of refraction increment and h is the thickness of the cell K_2. On the other hand, the fringes superposed on the image of K_2 formed by the combination of the second and third beams do not shift since they both pass through the solvent in K_2 which does not sedimentate. Consequently the sets of fringes in the second and third images serve as references from which the movement of the fringes produced by the first and second beams in the first and second images on P can be determined. The use of K_1 allows white light fringes to be used for calibration purposes. Since a relative displacement of the fringes on the photographic plate can be measured with high precision, the present interferometer arrangement is much more reliable than the one used in the past.[4] It will be observed from figure 4 that light can pass through K_2 once each revolution and only while the rotor turns through a small angle determined by the properties and position of the lens L_2 of the slit K^1 and the width of S_1. In practice this angle is about 0.003 radian which gives sharp fringes over each of the images of K_2 on P. Consequently precise values of the concentration are obtained for each point in the cell K_2.

As soon as the temperature of the rotor reaches a steady value the interferometer fringes are adjusted so that they are parallel or preferably perpendicular to the radius of the rotor and photographed both in monochromatic and in white light. The centrifuge is next accelerated to operating speed as quickly as possible and the drive shaft disconnected. This allows the centrifuge rotor to "coast" freely during the sedimentation and completely eliminates the troublesome problem of rotor "hunting." The fringes are again photographed both in white and in monochromatic light at regular intervals until the observed concentration gradient in K_2 stops changing, i.e. until equilibrium is effectively established.

Figure 5 shows the distribution of concentration at different times during the sedimentation of human albumin and figure 6 shows the log C at radius X plotted versus $X^2 - X_0^2$, where X_0 is the peripheral radius of the centrifuge cell, for sucrose dissolved in water after 58 hours of centrifuging. According to theory this should be a straight line, the slope of which gives the molecular weight if the sedimenting substance is mono-disperse. The value obtained for the molecular weight of sucrose was 343 as compared with the known value of

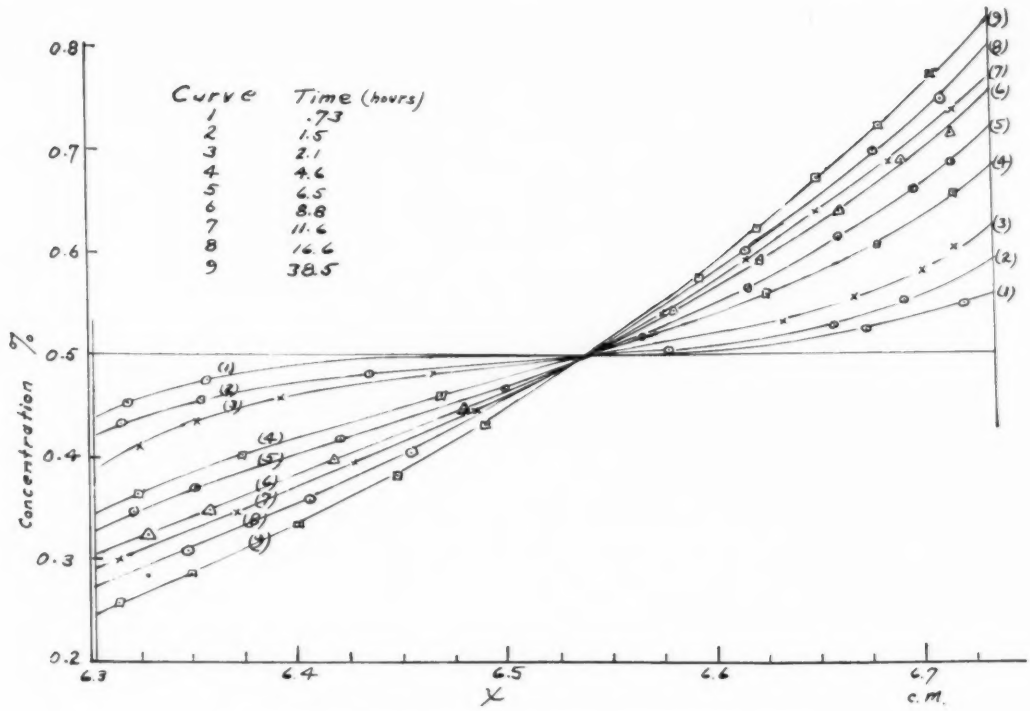

FIG. 5. Distribution of concentration during sedimentation of albumin.

342.3. The overall precision of the measurements made while the rotor is spinning gives a value of the molecular weights to about three significant figures over the molecular weight range above 100.

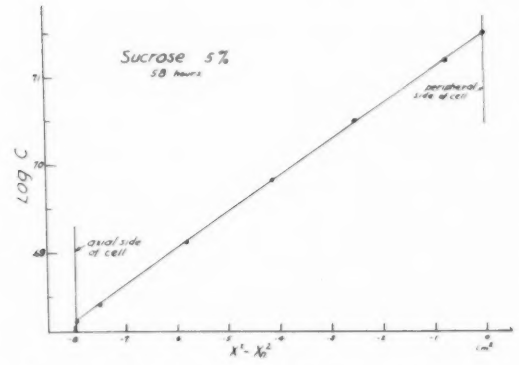

FIG. 6. Log C versus $X^2 - X_0^2$ for sucrose after 58 hours.

It was soon found that, in practice, equilibrium was established in the centrifuge cell much quicker than should be expected from the well-known formula which applies when the rotor speed is constant (1). In the above experiments since the rotor is "coasting" its speed is decreasing very slightly and this allows equilibrium to be established in a much shorter time. Archibald (7) has shown theoretically that if $1/N(dN/dt)/4\pi^2N^2S << 1$, where S is the sedimentation constant and N the rotor speed, equilibrium will remain once it is established in the cell. As a result a considerable amount of centrifuging time may be saved by adjusting the air pressure around the rotor to a value that will introduce just the proper deceleration to give a minimum time for the establishment of equilibrium. In all cases these decelerations are so small, i.e. the order of a few rev. per sec. per day, that the rotor temperature remains sensibly constant. In this way the equilibrium times in some cases may be reduced from

the order of weeks to days. In addition to the measurement of molecular weights the equilibrium ultracentrifuge also may be applied to the determination of molecular weight distributions.

It is indeed a pleasure to acknowledge my indebtedness to Dr. W. C. Simpson and Mr. K. D. Williams for their most effective collaboration in this work.

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A BRONZE STATUETTE IN CINCINNATI AND ITS PLACE IN THE HISTORY OF THE ASKLEPIOS TYPES

MARGARETE BIEBER

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I. DESCRIPTION AND DATING

THE statuette (figs. 1–4) was formerly in the Jameson collection in Paris. It was exhibited in the Sambon Exposition and described by Salomon Reinach as of a very beautiful style (*très beau style*).[1] I saw the statuette in the Pietro Tozzi Galleries in New York. It is now in the Art Museum of Cincinnati.

Mr. Tozzi and Mr. Adams, the director of the Art Museum in Cincinnati, have given me permission to publish this fine piece.

The large statuette is $9\frac{1}{2}$ inches high. The bronze is of excellent preservation, although the surface is corroded in some places. The right arm at the elbow and both legs above the ankles were broken, but nothing is missing except the object in the right hand. A small rounded piece adheres to the inside of the hand below the thumb and second finger. This must have been the staff of the wandering healing god, around which the sacred snake was coiled. The right arm was leaning on this staff, and therefore the right shoulder is lower than the left one. The thumb and second finger held the staff, while the other fingers were laid loosely against it. The left hand is laid against the rear part of the hip under the himation, whose open vertical edges are held together by it. The mantle covers all of the left arm, the left shoulder, most of the back except the right shoulder blade, and is drawn under the right armpit to the front. It leaves the right arm and the whole breast free. Its upper part is laid in a large overfold, which crosses the body with a turned up edge, so that it makes a sharp diagonal borderline between the overfold and the lower part of the himation. The upper ridge of the overfold is rolled to a thick bunch below the breast, with little loops at the two sides, where it meets the parts coming from the left shoulder and from the back.

The feet are placed side by side; the right leg is a little bent and relaxed. The elegant shoes are open for the toes.

The head is slightly turned to the right. It is crowned with laurel bound with a fillet, the ends of which fall down on the nape of the neck. The laurel wreath is given to Asklepios as a savior and as the son of Apollo. It is represented on coins with the head of Asklepios from Epidauros, Aegion, Rhegion (with Hygeia on the reverse), Kos, and on coins of the second century B.C. from Pergamon with the inscription of Asklepios Soter (ΑΣΚΛΗΠΙΟΥ ΣΩΤΗΡΟΣ) or Asklepios and Hygeia (ΑΣΚΛΗΠΙΟΥ ΚΑΙ ΥΓΙΕΙΑΣ)[2]. The full hair lies in heavy locks on the nape of the neck and at the sides, while it stands erectly brushed forward above the forehead. It thus makes a broad frame for the serious features. The long strands of the beard end in curls. The eyes are deeply sunk in their orbits. The iris is indicated. The cheeks are thin, so that the cheekbones bulge through the skin. There is a heavy fold on each side of the short and broad nose. The mouth has full lips which are slightly opened. The expression is very intense, agreeing well with the conception of a mature and compassionate physician.

The style of the statuette is Hellenistic. The attitude with the hand on the rear part of the hip

[1] Reinach, Salomon, *Répertoire de la statuaire grecque et romaine* **6**: 11, fig. 1. Paris, Librairie Ernest Leroux, 1930.

[2] Thraemer, article Asklepios, in Roscher, *Lexikon der Mythologie* **1**: 638, Leipzig, Teubner, 1884. Head, Barclay, V., *Catalogue of Greek coins, Caria*, 206–208, pl. XXXII, 2–5 (Cos), British Museum, 1897; *ibid.* Poole, R. St., *Alexandria*, 218 and 229, nos. 1706 and 1782, pl. V, 1892. Six, J., *Jour. Hellenic Stud.* **42**: 33, fig. 3, no. 3, 1922. Fritze, H. von, *Die Münzen von Pergamon, Abh. d. preuss. Akad. d. Wiss.*, 5 and 23–24, pl. I, nos. 12, 15, 18, 23, 41–43, 1910. Imhoof-Blumer, F., and Percy Gardner, *A numismatic commentary on Pausanias* (reprinted from the *Jour. Hellenic Stud.* **6–8**, 1885–1887), 43, pl. L, H (Epidauros); 86 f., pl. R XIX (Aegium); it is not Zeus, for whom the authors rightly call it an unusual type. Defrasse, A., and H. Lechat, *Épidaure*, figs. on p. 89, Paris, 1895.

FIG. 1-4. Asklepios, Bronze Statuette. Collection of Michael Schaible, indefinitely on loan to the Cincinnati Art Museum. Photos, John D. Schiff, New York. Courtesy Mr. Tozzi and Philip R. Adams, Director of the Cincinnati Art Museum.

is conceived in the third dimension (see the view from the back, fig. 3), and thus presupposes the activity of Lysippos. The strong sentiment in the face presupposes the activity of Skopas. But the rich modelling of the features goes beyond what we know of Skopas. His heads restrict the expression to the eyes and mouth, while the cheeks are smooth. Much more similar is the head of the bronze statuette of a philosopher in the Metropolitan Museum of New York, where the surface of the face is furrowed and modelled by serious thoughts.[3] If it is Hermarchos, as has been supposed, the date must be 270–260 B.C. The head of the statue of Demosthenes, by Polyeuktos, dated 280–279, with its cheekbones standing out from the meager cheeks, although different in mood, may also be compared for the style.[4] I believe, therefore, that the date of the bronze statuette is around 275 B.C. It is a superb example of Greek bronze-casting.

II. STATUES OF ASKLEPIOS BY KNOWN ARTISTS

It is not possible to name a definite artist for the statuette. We know from literature, mostly from Pausanias, more than a dozen Greek artists who worked statues of Asklepios. They are in chronological order:

1. Dionysos of Argos, in Olympia, votive offering of Mikythos, Asklepios, and Hygeia. Pausanias V, 26, 2–3.

2. Kolotes, in Kyllene near Elis, in ivory. Strabo VIII, 3, 4.

3. Alkamenes, in Mantinea. Pausanias VIII, 9, 1.

4. Thrasymedes of Paros, seated, in gold and ivory, half the size of the Olympian Zeus. Pausanias II, 27, 2.

5. Timotheos, in Troizen. It was considered to be the hero Hippolytos. Pausanias II, 32, 4.

6. Skopas of Paros, in Gortyn in Arcadia, youthful with Hygeia, in Pentelic marble. Pausanias VIII, 28, 1; and in Tegea, standing with Hygeia at the sides of Athena, in Pentelic marble. Pausanias VIII, 47, 1.

7. Bryaxis, in Megara, with Hygeia. Pausanias I, 40, 6. An Asklepios in bronze mentioned by Pliny XXXIV, 73.

8. Kephisodotos of Athens, son of Praxiteles, statue later in Rome, temple of Juno in Porticus of Octavia. Pliny XXVI, 24.

9. Nikeratos of Athens, later in Pergamon, Asklepios and Hygeia, later in the temple of Concordia in Rome. Pliny XXXIV, 80.

10. Phyromachos, in Pergamon, later in Bithynia. Polybios XXXII, 15, 4. Diodorus Siculus, XXXI, 46 (ed. Becker).

11. Damophon of Messene, in Messene, Asklepios with his sons. Pausanias IV, 31, 10; in Aigion in Achaia, with Hygeia. Pausanias VII, 23, 7; in Megalopolis, with Hygeia in relief. Pausanias VIII, 31, 1.

12–13. Timarchides and Timokles, from Attica, in Elateia in Phocis. Pausanias X, 34, 6.

14–15. Xenophilos and his son Strato, in Argos, group of seated Asklepios and standing Hygeia, in white marble. Pausanias II, 23, 4.

The list thus goes from the school of Pheidias in the late fifth century to the time when the Greek artists began to work for their Roman conquerors in the middle of the second century B.C. The oldest Asklepios named by Pausanias II, 19, 2–3 by Kalamis in Sikyon was hardly Asklepios, because beardless and holding a pine cone, and the same is probably true of the statue by Skopas in Gortyn (no. 6) and by Timotheos in Troizen (no. 5). These may have been other healing gods or heroes. In Lebadeia in Beotia was an image of Trophonius by Praxiteles which resembled Asklepios (Pausanias IX, 39, 4).

III. STATUES OF ASKLEPIOS ON COINS

Coins of the different cities represent some of the statues mentioned in literature and many statues in sanctuaries of which the sculptors are not named. When these statues or groups are represented inside a temple, we may assume that they represent the cult statues of the sanctuaries. This is most likely for seated statues of Asklepios, which are depicted inside and without the temple on coins of Trikka, considered to be the oldest

[3] Delbrueck, R., *Antike Porträts*, XXXVIII, fig. 13, pl. 26, Bonn, Marcus and Weber, 1912. Richter, Gisela, *The Metropolitan Museum of Art, Handbook of the Greek collection*, 124–125, pl. 103a, 1953; eadem in Arndt, P., *Griechische und Römische Porträts*, pl. 1123 and figs. 1–6 in text. Bieber, Margarete, *The sculpture of the Hellenistic age*, 68, figs. 230–231, New York, Columbia Univ. Press, 1955.

[4] Bernoulli, J. J., *Griechische Ikonographie* 2: 66–84, pls. XI-XII, Munich, Bruckmann, 1901. Arndt, *op. cit.*, pls. 1111–1120. Feletti-Maj., B. M., Museo nazionale Romano, *I Ritratti*, 19, no. 18, Rome, 1953. Poulsen, Vagn, *Les portraits grecques*, nos. 27–28, pls. XIX-XXII, Kopenhagen, Publication de la Glyptothèque Ny Carlsberg, no. 5, 1954. Bieber, M., *op. cit.*, 66–67, figs. 214–229.

sanctuary of Asklepios[5] (Ilias IV, 202–204; Strabo, *Geographica* IX, 5, 17), and of Epidauros and Pergamon, the most renowned ones. The ones in Epidauros appear from the fourth century B.C. to the Antonine period and thus must represent the statue of Thrasymedes (No. 4).[6] The seated statues on coins of Pergamon appear from the time of Eumenes, when they were minted probably on the occasion of the victory celebration, the Nikephorion, in 183 B.C., until the Antonine period. They have been brought in connection with Phyromachos (No. 10).[7] This statue, however, was carried away in 157 B.C. by Prusias of Bithynia (Polybios, *Historiae* XXXII, 15, 14. Diodoros Siculus, *Bibliotheca Historica* XXXI, 46). It is, therefore, more likely that it was a work by Nikeratos (No. 9), which later may have been brought from Bithynia to Rome. We may assume that most of these cult statues were chryselephantine, of gold and ivory, or akrolithic, of gilded wood and marble. The one by Skopas in Gortyn (No. 6), however, was in Pentelic marble. Free variations of this group with Hygeia, or of the one in Argos by Xenophilos and Strato (nos. 14–15), showing him seated and her standing, are in the Vatican and in the Glyptothek Ny Carlsberg.[8]

IV. ASKLEPIOS IN SCULPTURE

Much more frequent than the seated are the standing statues of Asklepios, to which class the Jameson statuette belongs. The oldest and most frequently reproduced type found in statues, statuettes, reliefs, and coins is the one which we might call the Asklepios Neugebauer, because this scholar has written the best study on its many copies and adaptations (figs. 5–8).[9] It has been ascribed to Alkamenes (No. 3), although the coins of Mantinea do not agree with the sculptured monuments.[10] On the other hand, the type is found on many coins in other places of the Peloponnesus: Argos, Boeae, Patras, Troizen, Las, Orchomenos, Asine—the latter inside a temple[11]—and with Hygeia in Corinth, where Pausanias (II, 4, 5) mentions the two sculptured in white marble.[12] It is, however, also represented on coins, many from the fourth century B.C. to the third A.D. in Athens.[13] As the sanctuary of Asklepios was founded on the south slope of the Acropolis around 420 B.C. and at that time Alkamenes was the leading artist at Athens, it is indeed quite possible that the original creation was one by Alkamenes made for Athens.

[5] Gardner, Percy, ed. R. S. Poole, *Catalogue of Greek coins, Thessaly*, 52, no. 17, pl. XI, 13, British Museum, 1883.

[6] Imhoof-Blumer and Gardner, *op. cit.*, 43, pl. L, III–IV (the latter inside a temple) and 161, pl. GG, VII. Gardner, Percy, *Catalogue of Greek coins, Peloponnesus*, 156, no. 7 and 159, no. 30, pl. XXIX, 14 and 23, 1887. Defrasse and Lechat, *op. cit.*, fig. on p. 83; *cf.* the reliefs, pp. 84–87. Holländer, E., *Plastik und Medizin*, 70, fig. 23; *cf.* the reliefs, p. 69, fig. 22, and 72, fig. 25, Stuttgart, F. Enke, 1912. Kavvadias, P., *Fouilles d'Épidaure*, 22, pl. IX, no. 21, 1891.

[7] Fritze, H. von, *op. cit.*, 39–41, 47 and 50–52, pls. I, 29; V, 15 and 17; VIII, 7, 8, 16, 18, 19 (inside a temple). Pick, B., "Die Neokorie-Tempel von Pergamon und der Asklepios des Phyromachos," *Festschrift für Walter Judeich*, 37–40, figs. 7–9, 11–12, 14, 1929. Wroth, W., ed. Poole, Reginald Stuart, *Catalogue of Greek coins, Mysia*, 155, pl. XXXI, 5 (inside a temple), British Museum, 1892.

[8] Amelung, W., *Die Sculpturen des Vaticanischen Museum* 2: 602–605, Galleria delle Statue no. 399, pl. 51, 1908. Arndt, P., *La Glypthothèque Ny Carlsberg*, pl. 96, 1896–1912. Poulsen, F., *Catalogue of ancient sculptures in the Ny Carlsberg Glyptotek*, 88, no. 92, Billedtavler, pl. VII, 1951. Holländer, *op. cit.*, 141–143, fig. 71.

[9] Neugebauer, K. A., *Asklepios*. Ein Beitrag zur Kritik römischer Statuenkopien, 78. *Winckelmannsprogram* der archaeologischen Gesellschaft zu Berlin, 1921. Lippold, G., *Die griechische Plastik, Handbuch der Archaeologie* 3: 191, 1950. Kjellberg, Lennart, "Asklepios" in *Sprakvetenskapliga Sällskapets förhandlungar*, 1894–1897, 12–43, 70–112, Upsala, Universitets Arsskrift, 1898.

[10] Gardner, Percy, ed., R. St. Poole, *Catalogue of Greek coins, Peloponnesus*, 187, pl. XXXV, 9, 1887. Imhoof-Blumer and Gardner, *op. cit.*, 93, pl. S XV. Kjellberg, *op. cit.*, 90–92, 105–112, replicas 105–107, in note 2. *Cf.* Reisch, E., Oest. *Jh.* 1: 88, 1898.

[11] Imhoof-Blumer and Gardner, *op. cit.*, 37, pl. K XXXV, Pausanias II, 21, 1 (Argos); 63 f., pl. O XIV, Pausanias III, 22, 13 (Boeae); 81, pl. Q XXIV, Pausanias, VII, 20, 9 and VII, 21, 14 (Patras), in stone except for the dress, thus certainly an acrolith; 162, pl. GG XIV (Troizen) in temple. Gardner, P., ed. R. St. Poole, *Catalogue of Greek coins, Peloponnesus*, 113: pl. XXIII, 2 (Asine); 135, pl. XXXV, 2 (Las); 190, pl. XXXV, 18 (Orchomenos). See also the Asklepios on the votive relief from Patras: Holländer, *op. cit.*, 105, fig. 44.

[12] Head, Barclay V., ed. R. St. Poole, *Catalogue of Greek coins, Corinth*, 80, 83, 89, pl. XX 20, XXI 5, XXII 10, 1889. Imhoof-Blumer and Gardner, *op cit.*, 25, pl. F CXVII. Similar coin from Teos, Holländer, *op. cit.*, 59, fig. 12.

[13] Imhoof-Blumer and Gardner, *op. cit.*, 150, pl. EE III-IV. Pausanias, I, 21, 4 (Athens), Barclay Head, ed. Poole, Reginald, *Catalogue of Greek coins, Attica*, British Museum, 109, pl. XIX, 4, 1888. Svoronos, J. N., *Das Athener Nationalmuseum*, 3 v. with continuous numbering, Athens, Eleftheroudakis Verlagsgesellschaft, 1908, 1911, 1937. Coins in text 266, fig. 146. Shear, Josephine, Athenian imperial coinage, *Hesperia* 5: 312–313, fig. 19, 1936.

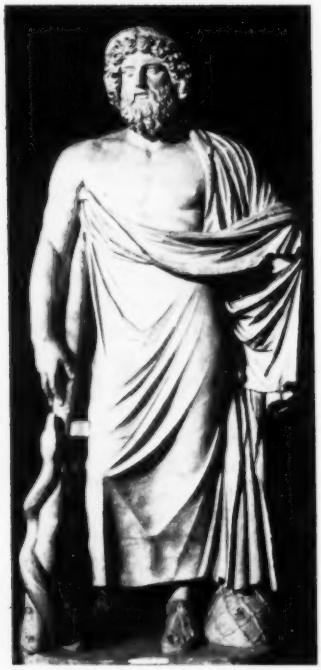


FIG. 5. Asklepios, Statue, Naples. Photo. Alinari, 11072.

FIG. 6. Asklepios, Statue, Florence. Photo. Alinari, 1221.

FIG. 7. Asklepios, Statue, Lateran Museum, Rome. Photo. Alinari, 6360.

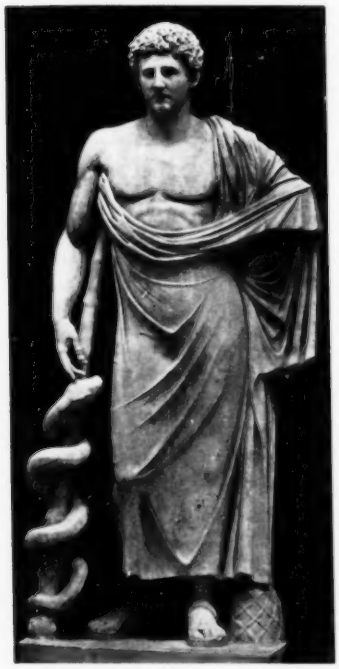


FIG. 8. Asklepiad, Statue of a physician, Rome, Vatican. Photo. Moscioni, 2297.

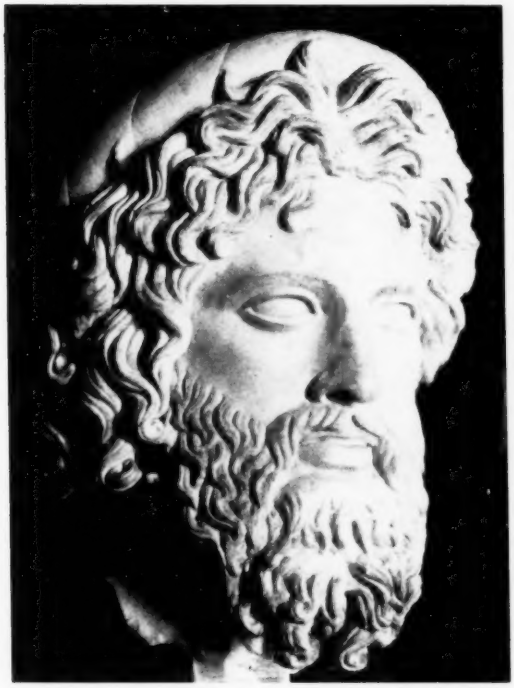


FIG. 9. Head of Asklepios, found in the Thermae of Caracalla. Rome, Museo Nazionale Romano. Photo. Moscioni, 9200.

From this center of Greek civilization other artists took the inspiration for their conception of the god of healing. Thus the coins of Megara, where Bryaxis created a bronze cult statue (No. 7), show the Neugebauer type with a little stronger movement; but when represented with Hygeia, he has a different type with reversed sides, the serpent-entwined staff under the left armpit (see below).[14] In Pergamon we also find the Neugebauer type, and indeed so frequently that we may attribute it to Phyromachos (No. 10) who seems to have adapted it to the baroque style of his time,[15] just as the Athena Parthenos was adapted. It replaced the seated statue by Nikeratos (No. 9, see above). An Asklepios in the Neugebauer type is also attested for Kos by the Antonine coin in my possession (fig. 12) with the inscription KOIΩN (formerly in the Collection of Hermann Weber and last in the Collection of E. Gans).[16] The group is framed by an aedicula; the pediment is carried by two columns. The stance of Asklepios is somewhat wider than that of the Peloponnesian coins and the staff is set somewhat more obliquely. The portrait of L. Verus dates the coin in the Antonine period, the same time in which temple C in Kos was erected.[17] The Neugebauer type represents Kos also on the alliance coins between Kos and Halikarnassos, as well as between Samos and Kos.[18]

It has rightly been assumed that the Asklepios in his sanctuary on the island of the Tiber in Rome also had this type. Many Roman copies have been found in Italy, the best in Rome, formerly in the Antiquarium comunale, now in the Museo Nuovo on the Capitol (fig. 38);[19] and one also found in Rome, probably on the Tiber island, now in Naples (fig. 5); others in Florence (fig. 6), a statuette in Syracuse, and a statue in the Louvre with little Telephos.[20] One in the

[14] Imhoof-Blumer and Gardner, *op. cit.*, 5 f., pl. A VI-VII. Poole, *op. cit., Attica*, 123, pl. XXII, 4.

[15] Poole, R. S., *Catalogue of Greek coins, Mysia*, 127, pl. XXVI, 7; 144–148, pl. XXVIII, 17; XXIX, 1, 2, 9, 11 (in temple with Hygeia); 153–155, pl. XXX, 9; XXXI, 1, 3–5; 163–166, pl. XXXIII, 1–5. Fritze, H. von, *op. cit.*, 39–41, 47–48, pl. I, fig. 17; IV, figs. 10, 20, 21; V, figs. 9, 10, 12, 13, 16; VI, figs. 15, 21; VII, 13–15; VIII, figs. 1, 2, 4, 9, 10; IX, fig. 16 (the last three inside a temple); 15, 24. Amelung, W., in *Röm. Mitt.* **16**: 372, 1901 and **18**: 1–16, figs. 1–4, 1903. Deubner, Otto, *Das Asklepieion von Pergamon*, 7–10, figs. 1–3, 1938. Bieber, M., *op. cit.*, 107, fig. 423 (the Pergamene head). Mustilli, D., *Il Museo Mussolini*, 146 Sala IX, no. 11, pl. LXXXVII, fig. 326 (statue type Neugebauer with Pergamene head), Rome, 1939. The type represents Pergamon on the alliance coin with Mytilene: Worth, W., *Cat. of coins, Troas*, 214, pl. XLIII, 2, London, British Museum, 1894.

[16] Formerly in the Collection Hermann Weber, no. 6694; then in Collection Edward Gans, List 15, no. 3432, 1955; now in the possession of the author. A similar group of Asklepios and Hygeia on one base on a coin from Kyme: Wroth, W., *Catalogue of coins, Troas*, 122, pl. XXIV, 6, British Museum, 1894.

[17] Schazmann, P., ed. Herzog, R., *Kos* **1**: 42. Berlin, Heinrich Keller, 1932.

[18] Head, B. V., *Catalogue of Greek coins, Caria*, 112, no. 91, pl. XLIV, 4, British Museum, 1897, *cp. ibid.*, 97, no. 100, pl. XVI, 7 (Asklepios and Knidian Aphrodite).

[19] Neugebauer, *op. cit.*, pl. I. Mustilli, *Il Museo Mussolini*, 118–119, Sala VIII, no. 7, pl. LXXVI, fig. 289, Rome, 1939. Here list of replicas.

[20] Neugebauer, *op. cit.*, pl. II, 1, Syracuse; pl. II, 2, Florence; pl. III, 1, Naples. Amelung, *Führer durch die Antiken in Florenz*, 67 f., fig. 18 (Naples), München, Bruckmann, 1897. Kjellberg, *op. cit.*, pl. II (Florence). Holländer, *op. cit.*, 64 f., fig. 17 (Florence); 80, fig. 31 (Syracuse). Libertini, *Guida di Siracusa, Museo Archeologico*, 149, no. 690, fig. 44. Louvre, Mus. no. 345. Froehner, W., *Notice de la sculpture antique du Louvre*, 369 f., no. 400, Paris, 1878. See also Berlin,

FIG. 10. Athenian Coin. A: Head of Athena; B: Owl on Amphora, Statue of Asklepios. Photo. J. Guilmain. Courtesy, E. Gans.

Lateran (fig. 7) [21] seems to be of a more advanced type and, therefore, has been brought in connection with Byraxis, which is unlikely (see below). The heads, of which one in colossal size was found in the Baths of Caracalla and is now in the Museo Nazionale Romano (fig. 9),[22] have in their full hair a ring around which a broad fillet is wound, in contrast to the wreath on the Jameson statue. The hair is parted in the middle and the strands fall on the forehead.

There are many variations of the Neugebauer type. The ones from Pergamon have heads with effective hair waves in the baroque style of the time of Phyromachos.[23] The coin of Messene

FIG. 11. Coin of Kos. Silver. A: Head of Aphrodite; B: Statue of Asklepios. Magistrate Nikostratos. Formerly in the Berlin Numismatic Museum. Courtesy Professor Regling.

FIG. 12. Coin of Kos. Bronze. Collection Bieber. Asklepios and Hygeia in temple. Photo. J. Guilmain.

no. 68, Holländer, *op. cit.*, 47, fig. 8. Neugebauer, pl. III, 2. Blümel, C., *Katalog der Sammlung antiker Skulpturen* 4, *Römische Kopien griechischer Skulpturen des fünften Jahrhunderts v. Chr.*: 78, K 131, pl. 14, Berlin, Staatliche Museen. Verlag Schoetz, 1931.

[21] Neugebauer, *op. cit.*, pl. III, 3, Lateran.

[22] Helbig, W., ed. Amelung, W., *Führer durch Rom*, 3rd ed., 2: 126–128, no. 1340, Leipzig, Teubner, 1913. Replicas: Neugebauer, *op. cit.*, 17, figs. 3–8. Holländer, *op. cit.*, 77, fig. 29. Blümel, *op. cit.*, 6–7, K 129–130, pls. 12–13.

[23] See above, note 15.

which may reproduce the statue by Damophon (No. 11) shows a closer, classicizing adaptation.[24] Attic votive reliefs on the other hand reproduce the Neugebauer type more faithfully,[25] and therefore confirm the belief that here was the original creation by Alkamenes.

Like many other Greek statues of gods or heroes the Romans used the type for portraits. Such a one is certainly the beardless physician in the Vatican who carries the serpent staff as an Asclepiad, a disciple of Asklepios (fig. 8).[26]

When we compare the Jameson bronze with this most popular and long-living Neugebauer type, we find general agreement in the attitude as a whole: feet standing in the same plane but at some distance from each other; right arm hanging loosely and fingers touching the serpent staff; left arm covered by the himation and the hand laid on the hip. There are, however, significant differences: the staff is not thrust into the armpit, but held away from the body; the left hand does not rest in front of but behind the hip; the himation has a large overfold, so that the upper roll, laid below the breast, is not made by the upper edge of the mantle, but by the ridge of the overfold.

This combination of a voluminous roll of folds with a large overfold and the movement of the arms, somewhat forward for the right, backward for the left arm, confirm the date of the Jameson statuette in the Hellenistic period.

The overfold itself is, of course, a well-known feature in the classical art of the time of Phidias, for example in the Zeus of Dresden.[27] The difference from the Jameson bronze is obvious: the folds, particularly in the back (fig. 3), are much deeper and much more rounded in the bronze than those of the fifth-century statue despite its large size.

FIG. 13. Torso of Asklepios, Cassel. Photo. Bieber.

A similar overfold to that in the Dresden Zeus is also used in the type of Asklepios which, to judge by the numbers of copies, was the second most popular representation of the healing god. It was first investigated by Furtwängler. There are more than twenty marble copies, the best being in Leningrad, in Rome (Palazzo Altemps), and a good torso in Kassel (fig. 13).[28] It is also repre-

[24] Imhoof-Blumer and Gardner, *op. cit.*, 66, pl. I.

[25] Neugebauer, *op. cit.*, 33–35, figs. 11–12. Holländer, *op. cit.*, 109–110, fig. 47, and 122, fig. 56. Svoronos, *Das Athener National Museum*, 3 v., **1**, 1908, **2**, 1911, **3**, 1937. (Text and plates continuous); Athens, Eleftheroudakis Verlagshaus, 264–66, nos. 43–44, pl. XXXV, 1, Mus. no. 1346 and pl. XXXIV, 5, Mus. no. 1347, dedicated by Antidotos; 293–294, no. 73, pl. XL, 4, Mus. no. 1376; 681, no. 481, pl. CCLIV, 7, Mus. no. 104. The same type also from the Asklepieion in the Piraeus, *ibid.*, 356–357, no. 105, pl. LXV, 1, Mus. no. 1407; Loewy, in Arndt-Amelung, *Einzelaufnahmen antiker Skulpturen* **5**: 6–7, 20–21, nos. 1219, 1221, 1245, 4, München, Bruckmann, 1902. Attic coins with the type Neugebauer: Svoronos, 266, fig. 146, beginning in the second century B.C. and continuing into the third century A.D.

[26] Neugebauer, *op. cit.*, 38–42, fig. 13, pl. II, 3. Amelung, *Die Skulpturen des Vaticanischen Museums* **1**: 29–31, Braccio nuovo, no. 17, pl. IV, Berlin, Georg Reimer, 1903. Richter, Gisela, *Ancient Italy*, 54, fig. 174, Ann Arbor, Univ. of Michigan Press, 1955.

[27] Herrmann, P., Skulpturensamlung Dresden, *Verzeichnis der antiken Original-Bildwerke*, no. 68 with ill., Dresden, 1915. Treu, G., Der Dresdner Zeus, in *Festschrift für Otto Benndorf*, 99–110, pls. II–III, Wien, 1898. Schrader, H., *Phidias*, 56–60, figs. 35–37, Frankfurt am Main, Frankfurter Verlagsanstalt, 1924.

[28] Furtwängler, *Meisterwerke der griechischen Plastik*, 363–369, fig. 50, Leipzig, Giesecke and Devrient, 1893. Bieber, in *Ath. Mitt.* **38**: 265–268, fig. 1, 1913; eadem, *Die antiken Skulpturen und Bronzen in Kassel*, 16, no. 14, pl. XXII, Marburg, Elwert, 1915. Arndt-Amelung, Lippold, *Einzelaufnahmen antiker Skulpturen* **8**: 41–42, no. 2368, 1914 (Palazzo Altemps). Kjellberg, "Asklepios" in *op. cit.*, 82–84, replicas in note 2. Blümel, *op. cit.* **4**:

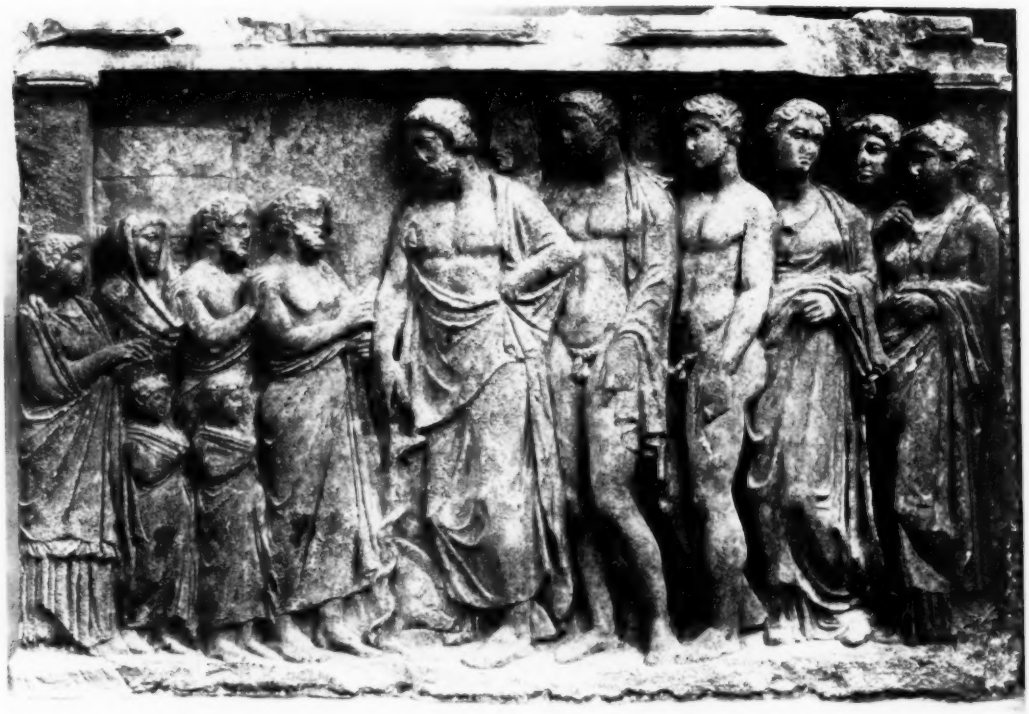


FIG. 14. Votive Relief to Asklepios and his Family, from Kynuria, in Athens. Photo. German Arch. Institute, Athens.

sented in free variations on votive reliefs to Asklepios which belong to the fourth century (fig. 14).[29] Later it was also used on a neo-Attic base in Naples,[30] and on boxes for medical instruments.[31]

When we compare the Jameson statuette with the two most popular classical types Neugebauer and Leningrad, I believe we can say that it is a Hellenistic combination and adaptation of these two. The next parallel to it seems to me the figure of Asklepios turning to his right and leaning on his staff represented on Athenian silver tetradrachms issued in 152–150 B.C. (fig. 10B).[32] It is used here as a symbol next to the owl, where in many cases celebrated statues, such as the Tyrannicides, are represented.[33] The superb head of Athena reproduces that of the Athena Parthenos (fig. 10A). A similar Asklepios occurs on a

8, K 132, pl. 15, 1938. Jones, Stuart, *Sculptures of the Palazzo dei Conservatori*, 231, Giardino, no. 7, pl. 90; *cp. ibid.*, 239, no. 46, pl. 93, Oxford, 1926. Mustilli, *Museo Mussolini*, 25–26, Sala del muro Romano, no. 20, pl. XX, 70. Here list of replicas and variations.

[29] Our fig. 14 is Athens, National Museum, no. 1402. Stais, V., *Marbres et bronzes du Musée national* 239, 1910. Svoronos, *op. cit.*, 351–352, no. 100, pl. XXXV, 4; Asklepios is followed by his sons and daughters. See also Duhn, F. von, in *Ath. Mitt.* **2**: 214–216, pl. XIV, 1887.

[30] Naples Mus., no. 6670. Ruesch, *Guida del Museo di Napoli*, no. 289. Asklepios as son of Apollo and a heroine here follow Zeus together with the sons of Zeus from heroines: Dionysos, Herakles, and Hermes.

[31] Holländer, *op. cit.*, 466–467, fig. 349.

[32] Head, Barclay V., ed. Poole, Reginald, *Catalogue of Greek coins, Attica*, 64, pl. XI, 6, 1888. Imhoof-Blumer and Gardner, *op. cit.*, 150, pl. EE II. Holländer, *op. cit.*, 60, fig. 13. Svoronos, Jean (Johannes Sboronos) finished by Behrend Pick, *Les monnaies d'Athènes*, pl. 49, 1–3, 6–13, Munich, Bruckmann, 1923–1926. Gans, E., *Numismatic fine arts*, List no. 15, no. 3422, 1955. Mr. Gans kindly lent me the coin for reproduction.

[33] Imhoof-Blumer and Gardner, *op. cit.*, 139–152, pls. BB, V, VI, VII, XII, XIII, XVI, XVII, XIX, XX, XXI; CC, I, VI, VII, VIII, XIV, XV, XVIII; DD, XIV–XV (Tyrannicides), XIX, XX; EE, I, V, VI, IX-XV.

FIG. 15. Statue of Asklepios, Johns Hopkins University, Baltimore. Photo. Ed. Althausen. Courtesy of the Institute of the History of Medicine.

FIG. 16. Statue of Asklepios of black marble, from Ostia, in the Museo Capitolino. Photo. Alinari, 27124.

Roman bronze medallion of the time of the Emperor Hadrian.[34] The classical period became the ideal of all following periods, the Hadrianic being one of its greatest revivals. In Athens the classical tradition lived on uninterrupted,[35] as is shown also by the Jameson statuette. It is still so near to the two earlier types that the date, early third century, is again confirmed.

There are no exact sculptural replicas of the Jameson statuette, but only a few Roman copies of a similar type, particularly a statue in Johns Hopkins University (fig. 15),[36] a mediocre one in Kopenhagen,[37] and one of the Hadrianic period in black marble (*bigio morato*) in a decorative style, found in Ostia and now in the Capitoline Museum at Rome (fig. 16).[38] In this statue the main difference is that the corner of the himation hanging from the left shoulder is visible, not hidden by the overfold. Its counterpart represents Zeus—and in many statues preserved for us it is doubtful whether Zeus or Asklepios is represented. This is also true for a decorative statuette in the Museo Chiaramonti of the Vatican,[39] and of a torso from Kos in Constantinople.[40] Similar Asklepios figures are also to be found on Attic votive reliefs.[41]

[34] Grueber, H. A., *Roman medallions*, 5, no. 15, pl. VI, British Museum, 1874. Holländer, *op. cit.*, 61, fig. 14. Toynbee, Jocelyn M., Roman medallions, *Numismatic Studies* **5**: 138 with note 106, pl. XL, 4, New York, The American Numismatic Society, 1944.

[35] *Cf.* Bieber, M., Atticism in the late fourth and the early third century, *The sculpture of the Hellenistic age*, 58–70, Columbia Univ. Press, New York, 1955.

[36] Robinson, David M., *Excavations at Olynthos* **12**: 136, note 88, pl. 182, 3, Baltimore, Johns Hopkins Press, 1946.

[37] Poulsen, F., *Catalogue of ancient sculpture of the Ny Carlsberg Glyptotek*, 90, no. 96, Billedtavler, pl. VIII, Kopenhagen, 1951.

[38] Jones, Stuart, *The sculpture of the Museo Capitolino*, 278, Salone 5, pl. 67, Oxford, The Clarendon Press, 1912. Holländer, *op. cit.*, 67, fig. 20.

[39] Amelung, *op. cit.* **1**: 420, Museo Chiaramonti 174C, pl. 43, 1903.

[40] Mendel, G., *Catalogue des sculptures* **3**: 18, no. 815, Mus. no. 1560, Musées impériaux ottomanes, 1914.

[41] Svoronos, *op. cit.*, 656, no. 410, pl. CLXXXVII, 4, Mus. no., 2933. Holländer, *op. cit.*, 121, fig. 55. See

FIGS. 17–18. Torso of Asklepios found in Olynthos. Photo. Courtesy of Professor David M. Robinson.

FIG. 19. Torso found in Oropos. Photo. German Archeological Institute, Athens, Oropos 13.

The Jameson statuette is certainly much more strongly in the classical tradition than is the third among the more popular types. This originated in the fourth century B.C. and before the middle of the century, for an example has been found in Olynthos, a town destroyed in 348 B.C. by Philip of Macedon (figs. 17–18).[42] Others were dedicated in Potidaea, Oropos (fig. 19), and Epidauros.[43] The serpent staff is shown under the left instead of the right armpit. The left arm hangs loosely over it, and the body leans to this side. The right hand is supported on the right hip above an overfold the curved folds of which spread out from beneath the fingers. The mantle has slipped down from the left shoulder and is held together in a knot under the armpit by the staff. From this point the folds radiate over the left arm. The execution of the earlier examples is rather flat. It becomes much more rounded in the many variations of this type which can be credited to the Hellenistic and Roman periods. Some add a larger triangular overfold, for example a torso in the Gallatin Collection in New York.[44] Others have a smaller and rounded overfold, like the statue set up in the wall of the Casino in the Villa Doria-Pamfili at Rome (figs. 20–22).[45]

The most frequent Hellenistic reworking of this type is the one where the left shoulder is also covered and the folds radiating from the armpit

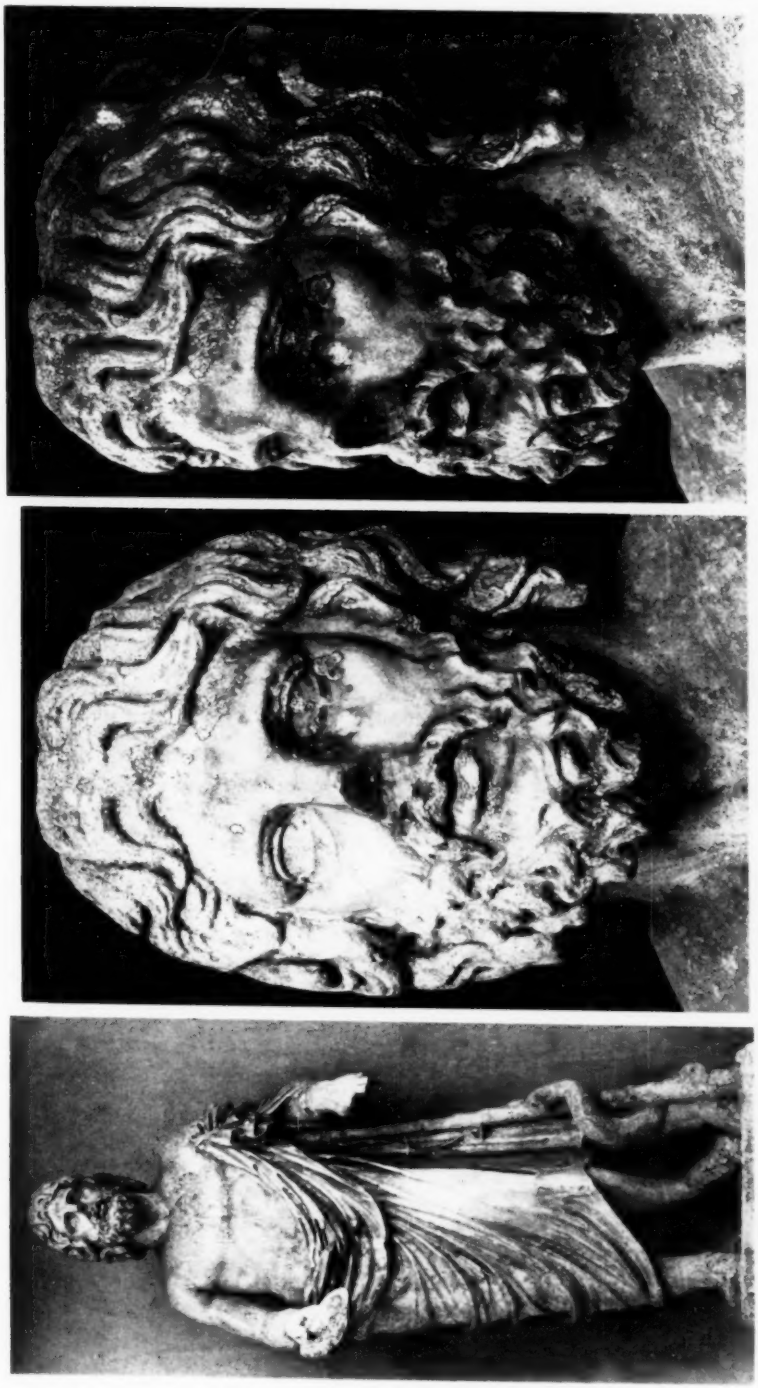
also Reisch, "Amphiaraos" in *Festschrift für Otto Benndorf*, fig. on p. 139.

[42] Robinson, David M., *Excavations at Olynthos* **12**: 130–137, pls. 115–119, Baltimore, Johns Hopkins Press, 1946.

[43] Robinson, *ibid.*, pl. 117 (Potidaea). Leonardas, B. I., *Praktika*, 59–62, 1887. Reisch, E., in *Festschrift für Otto Benndorf* "Amphiaraos" **143**; *cp.* **139–147** and *Arch. Anz.* 60, 1895 (Oropos, our fig. 19). Wolters P., *Ath. Mitt.* **17**: 1–15, pl. II (Epidauros), 1892. See also Robinson, *op. cit.*, 133–134, fig. 3 (statuette in Munich).

[44] Bieber, M., in Arndt, P., and Walter Amelung, *Einzelaufnahmen antiker Skulpturen* **15**: 42–43, no. 4487, 1938. Here list of replicas.

[45] Lippold, G., in Arndt and Amelung, *op. cit.* **8**: 35, nos. 2333–2335, 1914.



FIGS. 20–22. Statue of Asklepios, in Villa Doria-Pamfili, Rome. Photo Einzel-Aufnahmen antiker Skulpturen Nos. 2333–2335. Courtesy F. Bruckmann, Munich.

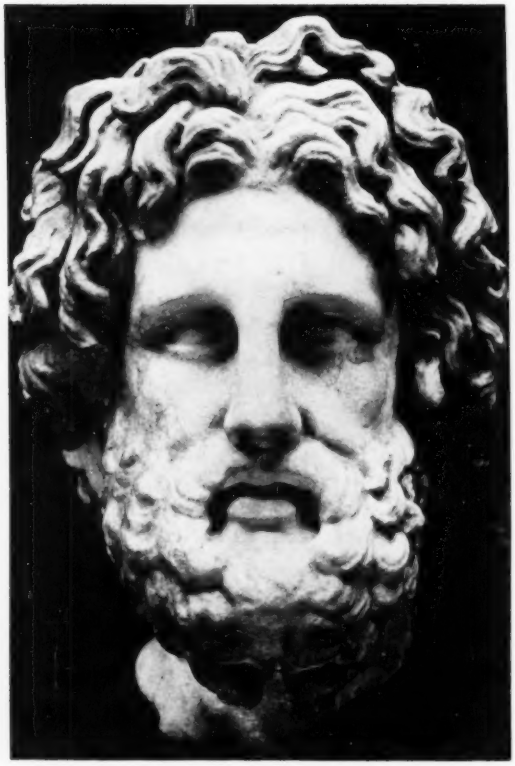


FIG. 23. Head of Asklepios, found in Melos, British Museum. Photo. Courtesy of the Trustees of the British Museum.

form a very characteristic half-circle from the shoulder to the wrist. This type is frequent on coins of the eastern Greek world, e.g. on those of Bargylia, the island of Rhodes, and combined with the head of the Koan Aphrodite by Praxiteles on silver tetradrachms of the island of Kos signed by the magistrate Nikostratos (fig. 11).[46] The Hellenistic sculptured representations are sometimes in agreement with the coin (fig. 11) in having the short and rounded overfold, as for example one from Kos in Constantinople;[47] but more frequently they have the large triangular overfold. Several have been found in Kos, one very fine one having found its way to the Dresden Museum,[48] and another to Constantinople (Istanbul, fig. 24).[49] The British Museum, the Louvre, and the Museum in Munich (fig. 25) also have torsos of this type.[50] A well-preserved statuette including the head is in Vienna (Wien, Austria, fig. 26).[51] It agrees with quite a series of replicas found in Epidauros (figs. 27–29).[52]

The most beautiful example of the head—the outlines of which the statuettes in Vienna (fig. 26), those from Epidauros (figs. 28–29), and the statue Doria-Pamfili (figs. 20–22) testify—is the celebrated head of Asklepios from Melos in the British Museum (fig. 23).[53] A similar although somewhat stronger one is on a torso from the Piraeus, probably from the sanctuary of Asklepios in Munychia.[54] This statuary type with the Melos type head has been brought into connection with

[46] Herzog, R., *Archiv für Religionswissenschaft*, 207, pl. of coins, I, 4, 1907. Head, B. V., *Catalogue of the Greek coins of Caria, Cos, Rhodes*, 73, pl. XI, 10 (Bargylia); 269, pl. XLIII, 6 (Rhodes); 205, pl. XXXII, 3-5 and XCV-XCVI, pl. XLV, 6 (Kos), London, British Museum, 1897. Macdonald, G., *Cat. of Greek coins in the Hunterian collection* **2**: 432, no. 10, pl. 54, 18, Glasgow, James Maclehose, 1901. Six, J., in *Jour. Hellenic Stud.* **42**: 33–34, fig. 3, no. 4, 1922. Mirone, M., *Revue arch.*, 317 f., 1922. Bieber, M., *Zeitschrift für Numismatik* **34**: 315–320, fig. 1, 1924.

[47] Constantinople (Istanbul) Mus., no. 1548. Mendell, G., *Catalogue des sculptures* **2**: 80, no. 318, Constantinople, Musées impériaux ottomanes, 1914. H. O. 47 m., thus about half life size.

[48] Dresden, Mus. no. 966. Herrmann, P., *Arch. Anz.* **7**: 158–159, fig. 2, 1892. Herzog, R., *Arch. Anz.* **18**: 196, 1903, and **20**: 10, 1905. Traces of red color on the mantle. Bieber, *Zeitschrift für Numismatik, loc. cit.*, 319, fig. 3.

[49] Constantinople, Mus. no. 1549. Not in Mendel, *op. cit.* Bieber, *Zeitschrift für Numismatik, loc. cit.*, pl. VIII, 2-3.

[50] British Museum no. 1696, Smith A. H., *Catalogue of sculpture in the Department of Greek and Roman Antiquities* **3**: 75, London, British Museum, 1904. Louvre Mus. no. F 2699. Munich: Arndt and Amelung, *op. cit.* **4**: 8, no. 915, 1899. Robinson, *op. cit.* 134, fig. 4.

[51] Schober, A., *Oesterr. Jahresh.* **22**: 8–15, fig. 3, 1926. Replicas of the three variations in notes 9–11.

[52] Athens, National Museum nos. 265, 267, 268. Stais, *op. cit.*, 95 and 105 (our figs. 32–34); *cp.* nos. 258, 262, 270, 297, 1814. Kavvadias, P., *Fouilles d'Épidaure*, pls. IX, 24; X, 28. Wolters, *Ath. Mitt.* **17**: 3, figs. 1 and 4, fig. 2, 1892. Replica in Venice: Arndt and Amelung, *op. cit.* **9**: 25, no. 2532, 1920.

[53] British Museum, no. 550, *Catalogue of sculpture* **1**: 290–291, 1892. Brunn-Bruckmann, *Denkmäler griech. u. röm. Skulptur*, pl. 230. Holländer, *op. cit.*, 73–78, frontispiece, figs. 26–28. Six, J., *Jour. Hellenic Stud.* **42**: 31–35, pl. I, 1922. Wolters, *op cit.*, 1–15, pls. II-III. Bulle, H., *Der schöne Mensch*, 398–499, pl. 231, München, Hirth, 1912.

[54] Stais, *op. cit.*, 89–90, no. 258. Cavvadias, *op. cit.*, 210. Wolters, *op. cit.*, pl. IV. Holländer, *op. cit.*, 79, fig. 30.

FIG. 26. Statuette of Asklepios, in Vienna. Photo. Paul Frankenstein.

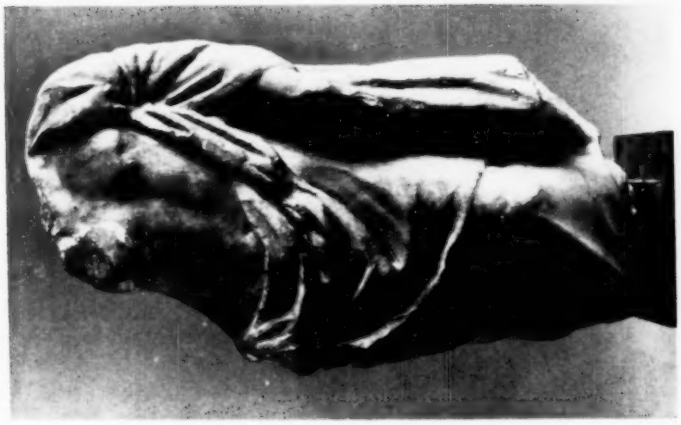
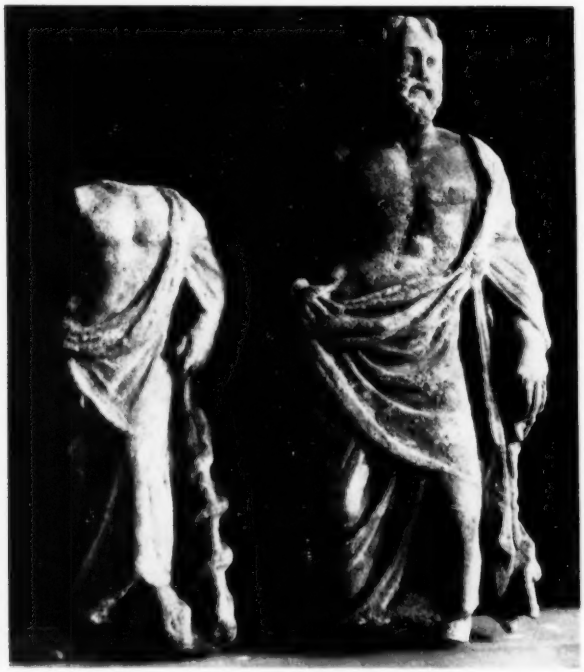


FIG. 25. Torso of Asklepios in the Museum of Munich. Courtesy Professor David M. Robinson.

FIG. 24. Torso of Asklepios, found in Kos, in Istanbul. Photo. Museum Istanbul.



FIGS. 27–28. Statuettes of Asklepios, found in Epidauros, in Athens. Photo. German Archeological Institute in Athens No. 53.

Skopas by Wolters and Arias,[55] with Bryaxis by Bulle, Amelung, Six, and Schober.[56] It appears indeed with Hygeia, as described by Pausanias (No. 7), on coins of Megara, while on others, where Asklepios is alone, the Neugebauer type is used.[57] Bryaxis is called an Athenian, but distinguished from an artist of the same name who worked the statue of Sarapis set up in Egypt by Ptolemy Soter around 285 B.C. (Clemens Alexandrinus, *Protreptikos* IV, 48, p. 37 St). This differentiation has been doubted by Lippold.[58]

The Bryaxis who worked around 350 in Athens on a base for a votive statue with riders and about the same time at the Mausoleum of Halicarnassos, can hardly be the same who created the portraits of Seleukos Nikator and statues in Patara, Rhodes, Knidos, and Daphne near Antioch. The name is Carian; and Caria, therefore, is probably the homeland of the Bryaxis who became the leading creator of gods in the time of the Diadochi.[59] There are certainly no Skopadic features in the creation of the Asklepios beyond those common to Hellenistic art in general. The head has a much softer spirit and gentler character than any works which can be ascribed to Skopas. The best reasons for the attribution to Bryaxis of the Melos statuary type (figs. 20–29) are the relationship to the coin in Megara and the plausible assumption that Bryaxis, so active in the region of southwestern Asia Minor, may well have worked for the islands of Melos and Kos too. The Asklepios attested by the coins of Kos (fig.

[55] Wolters, *op. cit.*, 1–15. Arias, P. E., *Skopas*, Quaderni e Guidi di Archaeologia, **1**: 122, pl. IX, 32, 1952.

[56] Bulle, H., *Der schöne Mensch*, 497. Amelung, W., *Ausonia* **3**: 127, 1908. Six, *op. cit.*, 31–35. Schober, *op. cit.*, 14–15.

[57] Imhoof-Blumer and Gardner, *op. cit.*, 5–6, pl. A, VI (Hellenistic type with Hygeia), VII (alone, classic type).

[58] Lippold, G., *Festschrift für P. Arndt*, 115–127, 1925; idem, *Die griechische Plastik*, in *Handbuch der Archäologie* **3**: 257–260, 1950. Picard, Charles, *Les Statues Ptolémaiques du Sarapieion de Memphis*, 239–248, 1955, is of the opinion that Bryaxis created the Sarapis in the time of Ptolemy I Soter for Memphis.

[59] Bieber, M., *The sculpture of the Hellenistic Age*, 83–84, 1955.

FIG. 29. Statuette of Asklepios, found in Epidauros, in Athens. Photo. German Archeological Institute Athens, No. 52.

11), and by statues and statuettes (fig. 24) from this site, looks like a further development of the Megara coin type: the exposure of the youthful body, the strong movement toward the left side with heavy leaning on the serpent staff under the armpit, are reminiscent of Lysippean compositions. It is likely that the Asklepios on the coin (fig. 11 B) may have reproduced a celebrated work like the head of Aphrodite on the other side (fig. 11 A), which represents the Koan Aphrodite by Praxiteles.[60]

The original of this Hellenistic type, developed from a fourth-century type, thus may have stood in one of the three temples which were erected in the sanctuary of Asklepios on the island of Kos. There is no seated cult statue as attested by coins for the three other most celebrated sanctuaries of Asklepios, viz. the two named by Herondas (*Mimiambus* IV, 1–2) at Epidauros and Trikka, and the one in Pergamon.[61] The earliest temple in Kos was built 300–280 B.C., the second *ca.* 200–150 B.C., while the third was erected in the Antonine period.[62] I would like to assign the type with the large overfold to the third-century temple, the variation with the small overfold, reproduced on the coin (fig. 11), to the second-century temple, while the group with Hygeia reproduced on the coin with the bust of Lucius Verus on the obverse (fig. 12) may have been erected in the Roman temple, as this "Neugebauer" type was very popular in the imperial period. In Kos, Hygeia was considered the wife of Asklepios and was represented with him on the altar by the sons of Praxiteles (Herondas IV, 4–5 and 17–24) and probably also on the broad bases preserved in the Hellenistic temples of the sanctuary.

The coins of Alexandria, the capital of the Ptolemies, for whom Bryaxis was active, testify to an Asklepios with a great swing such as the Kos type has, but apparently simpler in the drapery.[63] On the coins he holds his right arm to the side, with the hand holding a phiale over an altar; the left arm is wrapped in the mantle, but there is no overfold. A small number of statues of Asklepios has this simple arrangement, but their right hands hold the serpent staff instead of the bowl, as in a statue from the Museo Boncompagni in the Museo Nazionale Romano (fig. 30),[64] one in the Museo Chiaramonti of the Vatican (fig. 31),[65] and one accompanied by Telesphoros in the Casino of the Villa Borghese in Rome.[66] Some variations have the right hand on the hip like the Kos type, combined with the simple drapery. Thus a statue from Cyrene in the British Museum[67] has been named Aristaeus, the

[60] Bieber, M., *Zeitschrift für Numismatik* **34**: 315–320, fig. 1, 1924.

[61] *Cf.*, above, notes 5–7.

[62] Herzog, R., *Arch. Anz.* **18**: 1–12, plan fig. 2, 1903; *ibid.* **20**: 1–15, plan fig. 1, 1905. Schazmann, P., *Kos*, ed., Herzog, **1**: 3–13, 34–39, 42–48, 72–74, pls. 1–6, 16–21, 23–27, 37–42, 51, 1932.

[63] Poole, R. St., *Catalogue of Greek coins, Alexandria*, 83, 84, 160, 208, nos. 703, 705, 1315, 1613, pl. V. British Museum, 1892. Svoronos, *Die Münzen der Ptolemäer* **2**: 127, no. 844; **3**, pl. XI, 32 bronzes (Arsinoe II). Athens, 4 vols., 1804–1908. Six, J., in *Jour. Hellenic Stud.* **42**: 33, fig. 3, no. 2, 1922.

[64] Found in Rome on the Quirinal. Holländer, *op. cit.*, 62–63, fig. 16.

[65] Found in Ostia. Museo Chiaramonti no. 684. Amelung, *Skulpturen des Vat. Mus.* **1**: 777–778, pl. 84, Berlin, Georg Reimer, 1903.

[66] Casino in Villa Borghese, no. CIC. Holländer, *op. cit.*, 129, fig. 59. Arndt, P., and Lippold, G., in *Einzelaufnahmen ant. Skulpt.* **10**: 15, no. 2760, 1925. Right arm with upper part of staff and left hand with patera are restored.

[67] Smith, A. H., *Catalogue of sculpture* **2**: 257, no. 1485, British Museum, 1900.

FIG. 32. Statue of Asklepios in the Sanctuary of Juturna on the Forum Romanum, Rome. Photo. Moscioni 778.

FIG. 31. Statue of Asklepios, Museo Chiaramonti, Vatican. Photo. German Archeological Institute, Rome.

FIG. 30. Statue of Asklepios, Museo Nazionale Romano, Rome. Photo. Alinari 20109.

founder of Cyrene, who, like Asklepios, was considered a son of Apollo. Roman variations with the mantle drawn up to the breast are the Asklepios accompanied by a boy carrying a cock in the sanctuary of Juturna on the Forum Romanum (fig. 32),[68] and the one found in the thermae of Faustina at Miletus, now in Istanbul, accompanied by a boy carrying medical instruments, and a similar figure in the Berlin Museum.[69]

The Kos type is also used on Attic votive reliefs for Asklepios[70] and even for Demos, who stands opposite Athena, the snake between them belonging in this case to the Athenian goddess.[71] These, of course, are not exact copies, but adaptations to the use of the scene represented on the reliefs. Often the legs are crossed, which does not occur in the free standing statues, and Asklepios bends down more to the votaries or the sick who come to him to be healed.

V. VOTIVE STATUETTES OF ASKLEPIOS

When people dedicated votive figures or reliefs in the sanctuary of a deity, they probably often used the type of the cult statue at least for the general features of their votive offering. This occurs in Athens.[72] When the sanctuary had several temples of different periods, as in Kos, several types could be adapted. On the other hand, the sanctuaries frequented by many people from different cities might receive imitations of the images in the homeland of the votaries, or the cult statues of the most celebrated sanctuaries could be used. This explains why so many different types are found, for example, in the sanctuary of Asklepios at Epidauros, where the cult statue was seated. Beside the classical Neugebauer type attributed to Alkamenes (figs. 5–9)[73] and the Hellenistic type attributed to Bryaxis (figs. 23–29), there was a large statue with a combination of this type with the head of the classical Neugebauer type.[74] Of the Petersburg type (fig. 13) is the statuette dedicated by the priest Ploutarchos in the year 308, although the style seems Hadrianic (fig. 33);[75] a statuette has a combination of the Petersburg type with a youthful head of the Antonine period;[76] and another, a very sturdy figure in the Neugebauer type with a youthful head, was dedicated by Ktesias to the Soter in the late Roman period (fig. 34).[77]

The Jameson bronze is probably such a votive statuette, dedicated to Asklepios. Unfortunately, we do not know where it was found. I am strongly inclined to assign it to the sanctuary on the south slope of the Acropolis at Athens. It is a Hellenistic adaptation of the Asklepios Neugebauer, which was probably the cult statue created by Alkamenes for Athens; it is related to the statue beside the owl on the Athenian tetradrachm

[68] Vaglieri, *Bulletino communale* **31**: 172, fig. 82, 1903. Hülsen, Ch., *Forum Romanum*, 149, 1905. Holländer, *op. cit.*, 154, fig. 82; *ibid.*, 131, fig. 60. A similar Asklepios, with Telesphoros, in Palazzo Massimi alle Colonne, Rome. Arndt-Amelung, E. A. 7: 71, no. 2054, 1913.

[69] Found in the thermae of Faustina in Miletus. Istanbul, Mus. no. 1995. Mendel, *Catalogue des sculptures* **1**: 330–331, no. 124, Constantinople, Musées impériaux, 1912. Wiegand, Th., *Abhandlungen d. preuss. Akad. d. Wiss.*, phil.-hist. Klasse, Anhang **18**: 31–32, Berlin, 1908. Holländer, *op. cit.*, 135–138, figs. 65–66. Kjellberg, *op. cit.*, figs. on 96–97, pl. I-II. Neugebauer, K. A., in *Milet*, Ergebnisse der Ausgrabungen und Untersuchungen, ed., Wiegand, Th., vol. **1**, 9: Gerkan, A. von and Krischen, F., *Thermen und Palästren*, 97–98, pl. XXV, Berlin, Verlag H. Schoetz, 1928. Blümel, C., *op. cit.* **5**: Römische Kopien griechischer Skulpturen des vierten Jahrhunderts v. Chr., 11–12 K 211, pl. 25.

[70] Svoronos, J. N., *Das Athener National Museum*, 247–248, no. 29, Mus. no. 1332, pl. XXXVI, 2 and 264, no. 42, Mus. no. 1345, pl. XXXV, 2; 254, no. 31, pl. XXXVIII, 2, Mus. no. 1334. Loewy, E., in Arndt-Amelung, *Einzelaufnahmen ant. Skulpt.* **5**: 6, 7, 10, nos. 1220, 1224, 1225, and 14–15, no. 1236, 1902. Kjellberg, *Asklepios* **2**: 26. Holländer, *op. cit.*, 108–114, figs. 46, 48, 50. Walter, Otto, *Beschreibung der Reliefs im kleinen Akropolismuseum zu Athen*, 50, no. 81, 1923. Bieber, M., *Zeitschrift für Numismatik* **34**: 315–320, pl. VIII, 1, 1924.

[71] Athens, Mus. no. 2985. Svoronos, *op. cit.*, 661–662, no. 421, pl. CLXXXXVII, 1.

[72] Torsos: Athens, Mus. nos. 702–704. Arndt and Amelung, *Einzelaufnahmen* **3**: 26, nos. 718–720, 1897. Neugebauer, *op. cit.*, 30–31, figs. 9–10. Shear, T. Leslie, in *Amer. Jour. Archaeol.* **40**: 197–198, fig. 17, 1936. Others will be published by Evelyn Harrison in a volume on the sculptures of the Agora of Athens. For the reliefs, see above, note 25.

[73] Kavvadias, P., *Ephemeris Archaiologike*, 41–43, pl. II, 7–9, 1885; *idem*, *Fouilles d'Épidaure*, 22, pl. IX, 22–24, 1891.

[74] Athens, Nat. Mus., no. 263. H. 1, 75. Staïs, *Ephemeris*, 246, 1886. Lechat-Defrasse, *op. cit.*, 17. Holländer, *op. cit.*, 61–62, fig. 15.

[75] Athens, Nat. Mus. no. 264. Staïs, *Ephemeris*, 245–249, pl. XI, 2, 1886. Wolters, P., *Ath. Mitt.* **17**: 5, 1892. *Inscriptiones Graecae* IV², 436.

[76] Athens, Nat. Mus. no. 1809. Staïs, V., *Marbres et bronzes du Musée National*, 96, 1910. Holländer, *op. cit.*, 82, fig. 32. H. 0.70 m.

[77] Athens, Nat. Mus. no. 270. Staïs, *op. cit.*, 94. H. 0.36 m. *Inscriptiones Graecae* IV² 478. That the cult of Asklepios and dedications to him continued into the middle of the fourth century is proved by an inscription dated 355 A.D. *Inscriptiones Graecae* IV² 438.

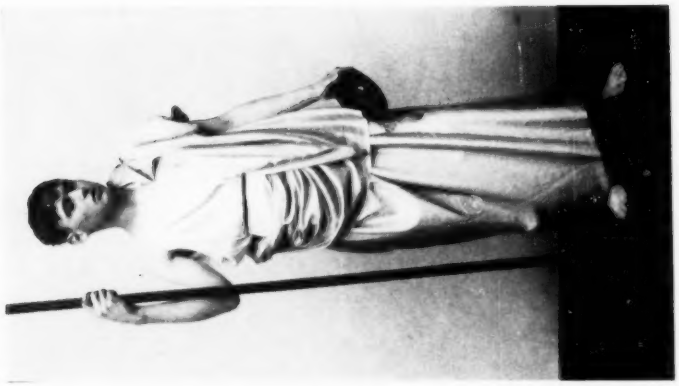


FIG. 35. Model for Asklepios type Petersburg-Kassel. Photo. Berlin Museum.

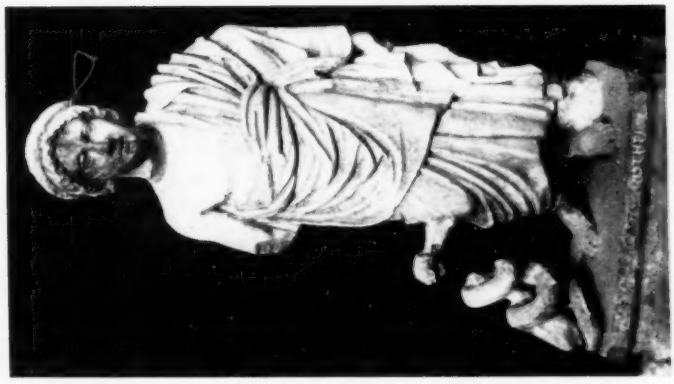


FIG. 34. Statuette of Asklepios, dedicated by Ktesias, found in Epidauros, in Athens. Photo. German Archeological Institute, Athens.

FIG. 33. Statuette of Asklepios, dedicated by Ploutarchos found in Epidauros, in Athens. Photo. German Archeological Institute, Athens.

FIG. 36. Statuette of Asklepios, in the Hygienische Museum, Dresden. Photo. Bruno Schroder.

FIG. 37. Side View of Statue of Asklepios in the Museo Nazionale Romano, Rome. Photo. Faraglia.

FIG. 38. Side View of Asklepios in the Museo Nuovo on the Capitol, Rome. Photo. Faraglia.

of the middle of the second century (fig. 10B); and it has the strong classical tradition characteristic of Atticism in the Hellenistic period.

The Jameson statuette is an original work. It is a sure indication of an original conception that, in contrast to the Roman contaminations, the drapery of the mantle is well understood. That the two classical types, the Neugebauer and the Petersburg-Kassel type, are based on a good tradition, is also shown by their understanding of the original drapery; yet there are typical mannerisms and errors found in many copies of the Roman period. For example, the severest copy of the oldest type, formerly in the Antiquario Comunale and now in the Museo Nuovo (the former Museo Mussolini),[78] shows in the side view (fig. 38) that the two vertical edges of the mantle, which hang down at the left side, meet with their backs in such a way that only a flat off-set, which is hardly visible, separates them from each other. Yet the two corners between the two vertical and the lower horizontal edges are clearly indicated by tassels, as is also the corner between the upper horizontal edge and the front vertical edge, where it hangs down behind the left arm. Only the corner between the upper horizontal and the rear vertical edge is not visible, because it is covered by the front part of the mantle. The arrangement is still clearer in the small replicas in the Museo Nazionale Romano delle Terme (fig. 37) and in Syracuse,[79] where the two lower tassels are laid on the omphalos next to Asklepios, and the separation of the ridges of the vertical folds is a little deeper, although still not as true as the original must have had it. The rear tassel is attached not to the corner between two edges but to the ridge of one edge. The same is true for the beardless Asklepiad in the Braccio Nuovo

[78] See above, note 19.

[79] Museo Nazionale Romano delle Terme, Courtyard, no. 52. Hannibaldi, G., *Notizie degli Scavi*, 81, no. 6, fig. 5, 1935. Syracuse: Neugebauer, *op. cit.*, pl. II, 1.

(above, fig. 8). The separation of the two vertical edges is indicated, but they are designed flat and parallel to each other. In the Asklepios in the Lateran (fig. 7) the two ridges are no longer separated at all. The whole side is brought forward like a façade, and the front and back are fused together. In a replica of the Collection Torlonia [80] the same façade-like arrangement has been used, and many parallel folds to the vertical ridges make the arrangement still more unclear. A small replica in the Museum of Hygiene (Hygienisches Museum) of Dresden, of which I owe photographs and sketches to Bruno Schröder (fig. 36),[81] is a variation in which the hand holds a fruit to feed the snake. Here the separation of the two parts of the mantle has entirely disappeared in favor of a fusion of the two ridges into the continuous back of a single fold.

In the second classical type, the Petersburg-Kassel (see fig. 13), not only the two lower corners, but also the two upper ones are indicated. As the living model (fig. 35)[82] clearly demonstrates, the corner between the upper horizontal and the front vertical edge hangs above the overfold, with its tasseled corner in front of the left thigh. The lower rear corner is not on the ground beside the front one, but hangs higher up. All this is clearly indicated in the Kassel replica (fig. 13), although the work is flat. A similar superficial but reliable arrangement occurs on a statue of the same type in the Museo Nuovo, formerly in the Atrium of the Capitoline Museum.[83]

When we turn to the Jameson statuette we can see that in contrast it is neither a flat, nor a schematic, nor a confused work, such as we find in Roman copies. The corner between upper edge and side front edge is, of course, hidden by the overfold as in the Neugebauer type (figs. 5–8), in contrast to the Petersburg-Kassel type (figs. 13 and 35). The second corner is indicated at the end of the overfold. The third corner hangs from the fold pressed against the body by the left hand. The fourth corner hangs outside the left leg (see figs. 3–4). Dress and body are in perfect balance. The folds are beautifully drawn, finely differentiated in the different parts of the drapery. The breast, shoulders, and the right arm as far as it is visible, are well modelled.

CONCLUSION

I therefore consider the Jameson statuette to be the votive offering of the work of an Attic artist of the early third century B.C., using motifs from the classical period, but transferring them into the Hellenistic style with good understanding for the organism of body and drapery. The sculptor was not a leading master, but an excellent and well-schooled artist.

The development of the various types for the representation of Asklepios was the following: The main, very harmonious types were created in the late fifth and early fourth centuries. The Hellenistic period used and varied these dignified types, tempering them to its own style and filling them with more individual and human features, with gentle and compassionate feeling. The Roman period copied the classical types, but often made mistakes, particularly when the sculptors combined them in an eclectic way with each other.

This development agrees with the history of medicine and its divine exponent, the healing god.[84] There were physicians already in the

[80] For Asklepios in the Lateran see note 21, and for the one in the Braccio Nuovo of the Vatican, note 26. Museo Torlonia, no. 94.

[81] Statuette in Dresden, H. 0.52. The designs were made when Bruno Schröder was director of the Albertinum, the Museum of Sculpture at Dresden.

[82] The model, fig. 35, was taken in the Berlin Alte Museum when Bruno Schröder was director of the Department of Greek and Roman Sculpture. The draping was arranged before the original statues there. See Bieber, M., *Griechische Kleidung*, pl. LI, 2–3, and LII, 1–2, Berlin, W. de Gruyter, 1928. Eadem, *Entwicklungsgeschichte der griechischen Tracht*, 32, pl. XVI, 1, Berlin, Gebrüder Mann, 1934. The young man who modeled for us is the deceased sculptor Wolfgang Horneffer.

[83] Jones, Stuart, *Sculptures of the Capitoline Museum*, 40–41, Atrio no. 41, pl. 6, Oxford 1912. Now in the Museo Mussolini (Nuovo) Sala VIII, no. 9.

[84] Heiberg, L. L., *Geschichte der Medizin*, in Müller, Iwan von, *Handbuch der Altertumswissenschaft*, ed. *W. Otto*, **5**, 1, 2; 91–118, 1925. Nilsson, M. P., *Geschichte der Religion*, *ibid.* **5**, 2, 1; 762–764, 1941. Edelstein, Emma J., and Edelstein, Ludwig, *Asclepius*. A collection and interpretation of the testimonies. Publications of the Institute of the History of Medicine, 2 v., Johns Hopkins Univ. **2**, 1945. This last work is a complete and very useful collection of the written evidence for Asklepios, but neglects the production of art. Statues, architecture, coins, etc., are excluded. When the image of Asklepios is discussed (**2**: 214–231) a great lack of knowledge is shown. Thus the seated Asklepios and Hygeia standing at his side is not a "favorite" grouping (p. 216) but unique (see above, p. 72). The assertion that Asklepios "always wore a chiton" (p. 217) shows lack of knowledge of art as well as of Greek dress. The healing god never wears

earlier periods, as testified by Homer, where Machaon and Podaleirios, the sons of Asklepios from Thessaly, accompanied the army to Troy and healed the wounded (*Iliad* II, 729–733; IV, 193–194; XI, 219, 833–836). Asklepios was himself a physician who received the knowledge of medicinal drugs (*pharmaka*) from his mythical teacher, the wise centaur Chiron (*Iliad* IV, 218–219). He was not yet a god but, like Hippolytos represented in Troizen by Timotheos in the guise of Asklepios (Pausanias II, 32, 4), he was one of the healing heroes of whom many were venerated in different parts of Greece.[85] Such a one was Amynos, for whom Sophokles was a priest; but later the poet dedicated an altar to Asklepios and composed a paian, a cult song for Asklepios (Philostratos, *Vita Apoll.* Tyana III, 17).[86] This is the time when the sanctuary on the south slope of the Acropolis was given a cult statue, probably by Alkamenes in the Neugebauer type (figs. 5–9). It was only then that Asklepios displaced the older healing heroes and gods, even as he displaced his father Apollo in Epidauros and in Kos, taking over his omphalos and laurel crown. This explains why it is that, in contrast to other gods, the type of Asklepios developed relatively late.

Another healing hero was Amphiaraos in Oropos. The sick who came to his sanctuary had to fast, bathe in a cool spring, and sleep, as in the Asklepieia (Pausanias I, 34, 1–3). I think it is possible that the torsos in Oropos (fig. 19) and in Olynthos (figs. 17–18) do not yet represent Asklepios but the older hero, particularly as the type is also used on the votive relief for Amphiaraos, like that of Archinos in Athens and others,[87] and later for the Hellenistic Koan type (figs. 11 B. 24–29). The medical school of Kos is built on the teaching of Hippocrates, who lived in the classical period when the two classical types (figs. 5–8 and figs. 13 and 35) were created. The physicians there practiced medicine in the sense of the oath of Hippocrates, today still sworn by young physicians. Like Hippocrates, who was born in the island of Kos but traveled through Greece and Macedonia, the physicians of the school of Kos were highly regarded and went to other countries to practice the healing art built on experience and observation of nature. Alexandria also brought forth great physicians, furthered by the knowledge of anatomy studied there. This is the period when medicine and its god became humanized, when the beautiful classical form of the type became enlivened with the sensitive expression of goodness and sincere compassion, as in the Jameson statuette (figs. 1–2) and the head from Melos (fig. 23).

Quite different was the development in Epidauros. Here the god, who had displaced his father Apollo, was seated. On the reliefs and in the votive statues he appears in the most diverse forms, just as he appeared in different forms to the devotees. Owing to their ardent faith, often expressed in prayer, and to their intense wish for recovery, they expected and sometimes experienced miraculous healing. Similar stories of miracle cures are told in modern times at Lourdes.[88] Hopelessly sick and disabled persons have found healing not only of nervous, psychological, and emotional ailments, but also of purely physical diseases by spiritual powers unknown to ancient and modern science. There were and are, of course, beside many conscientious and well-trained physicians, some greedy, nonprofessional healers, who exploited the despair and hope of the patients and invented miracles.

Through all the Hellenistic period, however, medicine, and with it the cult and representation of the healing god, kept a high standard. When the Romans took over Greek civilization, they furthered—as they did for art—medical practice.

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a chiton, a tunic, but always an himation, a mantle. The staff around which the snake coils, "attested as early as the work of Thrasymedes," of the fourth century (p. 280), is indeed already as early as the type Neugebauer of the fifth century (see figs. 5–8). The literary collection ought to have a counterpart in a complete collection of the artistic monuments depicting Asklepios, of which this paper gives only a small selection.

[85] Nilsson, *op. cit.*, 507–508. Reisch, *Festschrift für Otto Benndorf*, 139–147: Amphiaraos, Amynos and Trophonios were represented in the type of Asklepios.

[86] *Inscriptiones Graecae* II², 4510. Oliver, James H., in *Hesperia* **5**: 91–122, Athens, American School of Classical Studies, 1936.

[87] Votive relief of Archinos in Athens, Nat. Mus. no. 3369. Körte, A., *Ath. Mitt.* **18**: 253–255. Loewy, in Arndt-Amelung, *Einzelaufnahmen* **5**: 4, no. 1215, 1902. Frontispiece to the book by Herzog in following note. The crossed feet and the body inclined forward in many votive reliefs show that the reliefs are not exact copies of statues.

[88] Herzog, R., *Die Wunderheilungen von Epidauros*, Ein Beitrag zur Geschichte der Medizin und der Religion. Leipzig, Dieterich'sche Verlagsbuchhandlung, 1931. Cranston, Ruth, *The miracle of Lourdes*, New York, McGraw-Hill, 1955.

They were not interested in research, as the Greeks were, but their writers like Varro, Pliny, and others embodied the Greek medical knowledge which remained alive in the Greek world. Pergamon won world fame in the second century A.D. when Galen, later physician under Marcus Aurelius for little Commodus, was schooled here in 145–149. During the period of Hadrian and the Antonines, Asklepios became the guardian of the health of Emperors and Caesars and finally also of the general public. Pergamon and Kos received new temples in the Antonine period, to which many statues belong. The Romans and the Romanized Greeks continued to use the older types of Asklepios, particularly the classical ones, and combined them in their eclectic way (figs. 33–34), just as they did with medical remedies, philosophy, science, and art.

A MANUSCRIPT OF VOLTAIRE'S *CANDIDE*

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WHEN *Candide* was published, the Duc de la Vallière sent a letter to Voltaire (s.d.n.l., f. fr. 12901, f. 176) in which he stated:

> Le docteur Ralph s'est donc fait mettre sous la presse et Candide a paru il y a huit jours. jamais peut-être livre ne s'est vendu avec plus de vivacité, on le trouve charmant, l'on vous nomme, je nie, et l'on ne me croit pas, l'on pense comme moi sur le chapitre de Paris, c'est le seul qui soit trouvé faible, mangeons de jésuite est déjà un proverbe, la circonstance dans laquelle ce livre a paru est singulière, ces bons pères ne sont pas aujourd'hui dans leurs jours de triomphe, et l'affaire de Portugal ne leur fait pas honneur.

It is easy to conjecture from the Duke's little note that he had already before the appearance of the book had some acquaintance with its contents. His reference to Dr. Ralph as the author, his judgment of the twenty-second chapter which seems to have been an antecedent judgment, give a slight indication that he had known the work before the first edition.

Indeed, there is another bit of evidence which confirms this suspicion. Quérard, in *La France Littéraire* (Voltaire, Volume X, p. 323), is responsible for the legend (for in reality we do not know the document to which he refers) that the Duchesse de la Vallière had received the manuscript of *Candide:*

> Voltaire en avait envoyé le manuscrit à la Duchesse de la Vallière, qui lui fit répondre qu'il aurait pu se passer d'y mettre tant d'indécence, et qu'un écrivain tel que lui n'avait pas besoin d'avoir recours à cette ressource pour se procurer des lecteurs.

Beuchot repeated the story in the short introduction he wrote to *Candide*, but without giving any source for the legend. Evidently, he gave full credence to it. It is not surprising that Voltaire made copies of *Candide* before having the work published. We have Wagnière's story that he made a copy of the work for Charles Théodore at Schwetzingen, and there is a strong presumption in favor of that story since the Elector's references in his letters of the time lead one to believe that he had absorbed the general spirit of *Candide*.

In the light of all this evidence, it is surprising that those who have studied the circumstances giving rise to *Candide* have passively accepted the opinion that there is no longer any existing manuscript of the work. Perhaps the real reason for this attitude is the categorical statement of Morize in his very excellent edition of the conte (p. LXV): "Nous n'avons aucun manuscrit, aucun brouillon de *Candide*. Il est vraisemblable qu'il en existe encore des copies manuscrites, mais les bibliothèques de Paris et des départements n'en possèdent aucune." This statement coming from a worker, as scrupulous in his work as Morize has always been, is not encouraging to any youngster starting out on a career of research. Morize does qualify it with a reference to a manuscript owned by M. Paul Desjardins, but which, being posterior to 1775, is obviously of scant value in establishing a text or in throwing light upon its composition.

There is none the less a manuscript of *Candide* at the Arsenal Library, no. 3160 of that library's collection of manuscripts. It seems to have been there ever since the end of the eighteenth century, having been bought, according to the history of the library (Volume VIII of the *Catalogue général*, page 148) from the library of the Duke de la Vallière. It was described in the *Catalogue général* under the number 3160 when the catalogue was issued in 1888. How it could have been overlooked by all of us all this time is an incredible mystery:

> 3160. Voltaire, *Candide*.
> (mss. provenant de la Bibliothèque du Duc de la Vallière.)
> Voir: Cat. de Nyon N° 8864.

The Catalogue de Nyon is the six-volume catalogue of La Vallière's library made by the bookseller Nyon aîné around the end of the eighteenth century. Under the number 8864, he gave a succinct description of the item:

> 8864. Candide, ou l'optimisme, par Voltaire. Mss in-4°. Cart.

There is no doubt that this particular manuscript was the very one which Voltaire presented

to the Duchesse de la Vallière before the work was published. As such it should give an interesting version of the story not in its completed form (that was not achieved until the text was finally established in 1761), but in the form which Voltaire deemed worthy to circulate. In other words, this is the original version of *Candide*, or at any rate the original version until a more authentic manuscript can be located.

The manuscript is not in Voltaire's hand, nor is it in the characteristic hand of Wagnière. In one respect, it offers a very peculiar phenomenon: in places a wrong word was transcribed, immediately scratched out, and the right word forthwith added, not above this line, but on the line itself. One is tempted to infer that the author himself must have been writing his work *currente calamo*. It seems, however, more probable that the secretary doing the copying was familiar enough with the work to allow himself to take chances, and that these changes represent slips which he made and caught immediately. They are entirely too numerous, though, to admit of this interpretation. The only explanation at all plausible is that Voltaire dictated the work directly to his secretary. In fact, a manuscript catalogue at the B. N. states categorically that the manuscript was dictated by Voltaire.

In addition to these changes, there are corrections in Voltaire's hand. From the point of view of the story, many of them are of no great importance, although for one studying Voltaire's style, a small and apparently insignificant correction may take on an added importance. The point here is not that Voltaire was still touching up his copy in an effort to give it some final form. These corrections are straightforward evidence that the manuscript passed through his hands, that he gave it careful attention, and that he disposed of it as he wished:

P. 2	Pangloss enseignait la metaphysico-theolo-cosmolo-*mattologie*	for nigologie
7	De votre figure et de votre *mérite*	for taille
7	cinq pieds *six* pouces	for quatre pouces
12	chassé à grands coups de pied *dans le cu*	suppressed
15	Cunégonde *la perle*	for la plus belle
16.	Candide s'évanouit *à ce mot*	added
16.	rappela ses sens avec un *peu de* mauvais vinaigre	added
16.	en lui donnant un gobe . . . (the rest indeciferable)	suppressed
17.	capitaine de cavalerie qui l'*avait en droite-ligne* devait à	l'a = la suppressed
18.	cette maladie *nous* est particulière *aux Chrétiens*	nous added aux Chrétiens suppressed
19.	vingt-*huit* mille vérolés de chaque côté	huit suppressed
19.	*gens* changed to *stipandiaires*	
20.	*disait* repliquait	disait suppressed
24.	*Car si tout* car dit-il	suppressed
25.	il n'y a donc ni chute ni *perdition punition*	perdition suppressed punition added
28.	et lui *montra prépara*	montra suppressed prépara added
29.	un cabinet doré	for dérobé
33.	Don Issachar	*Don* added
33–4	*Ourdos* changed *passim* to *Don Issachar*	
45	scilitillation changed to *scintillation*	
52.	jusqu'à l'âge de *six*	for *dix*
54.	l'aga *qui homme* très galant homme	homme suppressed qui added
57.	*nommé Robek*	added
59.	que tous ceux qui le saluaient étaient tentés de le battre	added
59.	qu'on était tout déconcerté	suppressed
61.	*que*	suppressed

68.	*présent*	suppressed, then added
73.	sans toucher *aux* feuilles	for *ces* feuilles
76.	*Ne* manquez pas	for *n'en*
89.	*entre* sa Majesté	for *avec*
95.	*acheta* tout ce qui lui était	added lui
97.	dix mille *autres* piastres	added
103.	*vaisseau submergeant était un Espagnol et que celui du vaisseau submergé était un pirate Hollandais*	
103.	je t'ai *retrouvé*	for revu.
105.	*pensez*-vous	for croyez
110.	*soudain*	added
111.	un conseil *de Martin*	added
112.	on jouait *une pièce nouvelle*	added
112.	Monsieur je vous prouverai demain dans une brochure que vous avez eu tort de pleurer. La scène est en Perse et l'auteur ne sait pas un mot de persan. Les acteurs sont très mal coeffés et l'ouvrage est contre les bonnes mœurs. Ecoutez-moi bien. Candide ne l'écouta pas.	added
112.	(Westphallienne.) Je crois dit l'abbé etc. *come dans le manuscrit de Mr Ralph.*	added
113.	Nota que vers la fin de ce chapitre quand l'exempt dit *on arrête tous les étrangers*, il doit au lieu de ces mots dire ceux-cy: Monsieur on vous arrête pour avoir battu un clerc pendant que vous étiez à l'agonie.	

The manuscript can be helpful in determining the relationship between the three editions 59^a, 59^z, and 59^y. It will be recalled that 59^a was given as the *first* edition by Morize, and, after various modifications by Torrey, Tannery, and Gagnebin, has become once more the *accepted* first edition. 59^a is distinguished from 59^z in five places:

1) p. 31 59^a does not make a new paragraph beginning Mais il y a etc.
59^z does make a new paragraph Mais il y a etc.

2) p. 41 59^a "car—dit-il, tout ceci est ce qu'il y a de mieux, car s'il y a un volcan à Lisbonne, il ne pouvait être ailleurs. Car il est impossible que les choses ne soient pas où elles sont. Car tout est bien.
59^z "Car,—dit-il, c'est une nécessité que si un Univers existe, ce soit le meilleur des Univers. Or, dans le meilleur des univers, tout est bon, tout est bien, tout est au mieux; consolez-vous, réjouissez-vous, et buvons."

3) p. 84 59^a Nos filles se trouvèrent presque toutes en un moment
59^z Toutes nos filles se trouvèrent presque toutes en un moment

4) p. 125 59^a précisément
59^z précipitamment

5) p. 242 59^a does not contain the paragraph "Candide était affligé de ces discours," etc.
59^z contains the paragraph "Candide était affligé," etc.

The manuscript is in accord with 59^z in the first item, that is it begins a new paragraph at "Mais il y a une raison suffisante" (p. 18 of the manuscript). It contains the variant of 59^z "car, dit-il, c'est une nécessité que si un univers existe" etc. (p. 24 of the manuscript). The manuscript does not accord with either 59^a or 59^z in the third item. It offers rather a variant of its own: "Toutes nos filles se trouvèrent presque en un moment tirées ainsi à quatre soldats" (p. 49 of the manuscript).

As for the fourth item, the manuscript agrees

with 59^{r} in "ils se levèrent précipitamment" (p. 73 of the manuscript). Only in the last item does the manuscript agree with 59^{a}. The item, page 242 of 59^{r}, "Candide était affligé de ces discours," does not occur in the manuscript.

From these indications, we can only conclude that 59^{r} in its basic differences with 59^{a} offers a more authentic text than 59^{a}, always assuming that for textual purposes the manuscript does not carry final authority. It certainly shows an earlier version of the work than any printed text.

This last statement can best be seen in the way Voltaire struggled with the text of Chapter XXII in the manuscript. It will be recalled that La Vallière stressed that Chapter XXII (the Paris chapter) was the weak one of the book. Voltaire either judged the chapter weak or at any rate became convinced of its inadequacy, for in 1761, he gave it a thorough overhauling. It was, in fact, the only important modification he made in the whole work after the 1759 editions. That he had difficulty in composing this particular section is evident from the condition of the manuscript at this point. As a matter of fact, there are two "Chapter XXII" sketched in the manuscript. The first one carried three sections referring to the miracles at St. Médard Cemetery, the affair of the "billets de confession" and Damiens' attack upon the king.

Un moment après il passa près d'un cimetière, c'étaient des cris, des hurlements horribles. On eut dit que tous les morts étaient ressuscités pour faire cet épouvantable sabbat. Il vit des petites filles, des Abbés, des Colporteurs, des sacristains, des vieilles qui aboiaient, qui grinçaient les dents, qui se roulaient par terre, qui sautaient, qui chantaient des psaumes, qui tremblaient et qui buvaient en criant: Miracle, miracle.

Ah! bon Dieu! dit Candide à Martin, est-ce ainsi que la capitale d'un grand roiaume est faitte! Quelle différence de ce cloaque à la ville d'El Dorado.

Ils n'eurent pas fait cent pas qu'ils furent arrêtés par une foule de peuple qui criait encor plus fort que la première bande, autour d'une douzaine de biérres couvertes d'un drap noir avec chacune un bénitier au pied. Candide et Martin s'informèrent du sujet de ce tumulte. Un bon homme du quartier leur dit, Messieurs, est-ce que vous ne savez pas quel impôt on a mis depuis peu sur les morts. Candide lui jura qu'il ne savait rien de ce qui concernait les morts et les vivants de cette pauvre ville, qu'il était étranger, qu'il arrivait et qu'il comptait en partir incessamment.

Hélas, Mr. dit le bonhomme, on présente aux mourants depuis quelques mois des billets païables au porteur pour l'autre monde, que tout homme à l'agonie doit signer, et s'il ne signe pas, il n'est pas enterré. En voici douze à qui on refuse la sépulture. Cela mettra la peste dans la ville.

Le postillon qui conduisait les deux voiageurs eut beaucoup de peine à passer. A peine furent-ils arrivés à un carrefour voisin plus puant mille fois que tous les morts du quartier qu'ils virent tout en tumulte. Les boutiques se fermaient, on courait de tous côtés sans savoir où. On criait à l'assassin. Chacun sortait de sa maison. On hurlait-mille voix demandaient à Candide et à Martin: venez-vous de la cour? Est-il pris? A-t-il révélé ses complices? Candide et Martin aprirent enfin avec bien de la peine, qu'il venait de se commettre un attentat épouvantable, un crime inouï chez vingt autres nations, un assassinat qui faisait frémir et verser des larmes. Il se passa une heure entière avant qu'ils peussent gagner une hôtellerie un peu honnête. On leur servit à souper.

The second version of Chapter XXII in the manuscript does not contain these passages. In general, it is much closer to the text as it was printed. The section dealing with the Academy of Bordeaux and the red sheep, as well as the subsequent episodes have already been incorporated in the second version. Evidently, Voltaire was aware of his difficulties and was still hesitant about which version to adopt. The reason for this hesitancy is quite clear: Voltaire was having difficulty in grasping the reality of Paris. Having lost contact with it over a period of ten years, he could not tell whether his Paris was the Paris of the 40's (i.e., the Vision de Babouc) or the 50's. He tried to give it the structure of the 50's, but the Paris of the 40's kept interposing itself. Finally, Voltaire made a third version, as everyone now knows, beginning with the edition of 1761, in which the fifteen-page section (beginning Morize, p. 150, l. 65, and extending to p. 165, l. 269) was added to the second version. All he could do to round out the "reality" of 1760 was to invent the Marquise de Parolignac and her salon: it was sufficient to "bring to life" Chapter XXII. Even La Vallière who found the manuscript chapter weak and Grimm who thought that the original printed version of 1759 "ne vaut pas grand'chose" must have both been satisfied with the final draft.

We now come to the text as a whole. In spite of the tiresomeness of the technique, it is necessary to mark the variants and, if possible, draw some general conclusions concerning the importance of the manuscript in the interpretation of *Candide*. These variants for convenience have been established upon Morize's edition which is the standard. In each case we have given chapters and line. When necessary, we have explained the nature of the variant:

Title:	L'optismime	for L'Optimisme

Chapter I

16.	grands Seigneurs	for puissants
33.	theolo	for theologo
33.	mattologie	for nigologie
47.	doit avoir le plus grand château	for doit être le mieux logé

Chapter II

10.	Il n'avait	for n'ayant
11.	et mourait de faim	for mourant de faim et de lassitude
11.	la nécessité le contraignit d'aller demander l'aumône	for il s'arrêta tristement
19.	mérite	for taille
21.	six pouces	for cinq pouces
42.	tirer la baguette	for hausser
56.	aime	for aimait
58.	à la fois	omitted
62.	il essuya six	for deux
64.	douze mille	for quatre
66.	septième course	for troisième
72.	un grand sens	for génie
75.	dans tous les journaux	omitted

Chapter III

7.	telle que jamais	for telle qu'il n'y en eut jamais
9.	(mondes) possibles	added
16.	le (Te Deum)	for des
20.	en cendre	for en cendres
27.	acheva	for achevât
32.	(de même) Presque toute la province était ainsi détruite	added
41.	(chassé) pour les beaux yeux de Mlle Cunégonde	omitted
41.	(chassé) à grands coups de pied dans le cu	added
41.	dans le cu	suppressed
70.	l'emmena	for l'amena
73.	dans sa manufacture	for ses manufactures

Chapter IV

17.	il lui *fait* manger	for fit
29.	deffendre sa fille	for la deffendre
37.	il s'enquit *encor*	added
45.	*dans le* cu (main de V.)	for au cul.
46.	faire	for produire
61.	fut la *source*	for souche
66.	(génération) et qui est évidemment l'opposé du grand but de la nature i.e. qui souvent même empêche la génération	omitted
71.	Les Turcs, les Persans, les Indiens	for les Indiens, les Persans
100.	*leur* nature	for la nature

Chapter V

53.	(des mourants et des morts) Pangloss . . . *jusqu'à* raison universelle (59)	omitted
80.	consolait	for consola
87.	étant	for étant
101.	ou d'Opporto	omitted

Chapter VI

7.	un bel auto-da-fe au peuple	for au peuple un bel
9.	en cérémonie	grande omitted
20.	*d'une* mitre	de mîtres
28.	qui n'avaient *pas*	for point
38.	sans que je sache *même précisément* pourquoi	for sache pourquoi

Chapter VII

7.	prépara (main de Voltaire)	for montra
18.	la *bonne* vieille	bonne added
24.	la bonne *vieille*	for la bonne femme
32.	(rêver), *il* regardait	for et
59.	*répliqua la dame*	omitted
62.	coups de pied *dans le cu*	added
65.	le dos	for l'echine

Chapter VIII

18.	le fil de *l'*histoire	for son histoire
25.	je ne nierai *point*	for pas
31.	*Ourdos*	changed to Don Issachar
32.	les *filles*	for femmes
38.	rien *de si beau sur la terre*	for sur la terre de si beau
46.	qui *était*	for est
67.	quand je vis *sous* une mitre et *sous* un san benito	for vis dans un — et sous une
75.	*de* Bulgares	for des Bulgares
84.	m'a donc cruellement	bien omitted
87.	prête *à*	for de
100.	*Je goûte*	for j'ai goûté
107.	c'était jour	le omitted

Chapter IX

13.	et étend	vous omitted
14.	de *la belle* Cunégonde	la belle added
24.	il entre, *il* voit	for et
35.	bien *d'un* autre	for d'une
51.	qu'ils s'éloignent	for s'éloignaient

Chapter X

29.	qui *avaient fait révolter*	for qu'on accusait d'avoir fait
35.	d'infanterie *à discipliner* et	for à commander
56.	cette *vieille* femme	for bonne

Chapter XI

3.	Je n'ai pas *toujours eu*	for eu toujours
6.	*Clément 12* [1730–1741]	for Urbain dix
11.	en *grâce*	for grâces
18.	et qui me deshabillaient	omitted
42.	et en demandant au corsaire une absolution *in articulo mortis*	omitted
44.	on les *dépouille*	for dépouilla
48.	à *toutes*	for tous
60.	(point) *ici*	added
81.	de mulâtres contre mulâtres	omitted
94.	on *combattait*	for combattit
99.	*toutes* nos filles	added
109.	comme *chacun*	for on
110.	sans qu'on manquat aux cinq prières par jour ordonnées par Mahomet	omitted

Chapter XII

11.	*jamais* rien vu	jamais added
15.	les *uns* acquièrent	for autres
31.	ma mission est finie	for faite
40.	mais Mlle, si vous aviez eu la peste, *vous avoueriez que c'est un fléau cent fois plus horrible*	added
44.	Elle est (comme dans le texte)	
46.	âgée de *quatorze ans et demi*	for quinze
53.	*destruction*	for peste
54.	*m'amena*	for me mena
61.	(petit fort) *bâti*	added
84.	*dans* des bateaux	for sur
105.	fille *du* Pape	for d'un
116.	huit	for douze
124.	si vous ne m'aviez	pas omitted

Chapter XIII

4–7:	*La belle* jusqu'à *proposition*	omitted
4–7:	La belle Cunégonde saisit la proposition de la vieille, elle engagea	added
13.	et je me *sens*	for sentirais
19.	*Figuera*	for Figueora
31.	ne l'était *pas*	for point
33.	(officieux) *pût lui être utile*, son âme	added
43.	demeura avec Cunégonde	Mlle omitted
46.	(charmes) et lui promit de faire une grande fortune au Capitaine	added
52.	Amérique *occidentale*	for méridionale
71.	*étaient déjà connües*	added
72.	perdre *de* tems.	added

Chapter XIV

10.	était bon homme	un fort omitted

Chapter XV

6.	*se* furent retirés	added
18.	le père *Didrie*	for Croust
19.	prit-*il*	il added
42.	et je l'espère *bien* encore	added

Chapter XVI

5.	dans le camp *paraguain*	added
19.	que dira le Journal de Trévoux	omitted
39.	devint *perclue*	for percluse
40.	*aperçut*	for vit
51.	ils *font* des quarts	for sont
66.	sur la mousse	de omitted
84.	Tout est bien, soit, mais	omitted
86.	*Cambo*	for Cacambo
106.	et loin	bien omitted
114.	les mœurs et les lois	omitted
120.	*rapporter*	for aporter

Chapter XVII

7.	par le plus court	chemin omitted
25.	*leur espérance*	for leurs espérances
29.	emplissons de cocos	le omitted
41.	les porta *longtemps*	added
44.	de rochers en rochers	for de rocher en rocher
49.	(forme) et d'une matière brillante, portant des hommes et des femmes	omitted
67.	(dans) *le* (moment)	for ce
70.	*leur divertissement*	for leurs divertissements
73.	(par) *signe*	for signes
86.	une odeur de cuisine délicieuse	for délicieuse de cuisine
88.	car *il faut savoir que*	for tout le monde sait
89.	(né) au *Pérou*	for Tucuman
101.	*de la maison*	for de l'hôtellerie
110.	pièces	d'or omitted

Chapter XVIII

12.	(lambris) *du pays*	added
17.	colibris	for colibri
18.	diamant	for diamants
20.	ne suis âgé *que*	for je suis âgé de cent soixante et douze
63.	le vieillard	bon omitted
89.	(situé) *au bout*	for à un bout
97.	(les) *revêtirent*	for vêtirent
127.	*il* (se mit)	for Candide
132.	ce n'était pas	for est
155.	quand *il vous plaira*	for quand vous voudrez
161.	*une* espace	for un
164.	ordonner	for donner ordre
166.	conduit	for conduits
186.	prétieux	for curieux

Chapter XIX

4.	de nos voyageurs	deux omitted
10.	et y périrent	for y furent abîmés
13.	(quelques) journées	for jours
25.	de notre félicité; ils entrent dans Surinam, la première chose dont ils s'informent	
25.	p. 126, l. 25 to p. 130, l. 60	omitted
69–77	Hélas! dit Candide en buvant et en pleurant, je sens bien malgré toute ma passion que je ne peux aller à buenos Airès. Mon amour m'aveuglait. La Sainte Hermandad m'arrêtera. Le meurtre de l'inquisiteur me fait toujours trembler. Mon cher Cacambo, voici ce qu'il faut que je fasse. . . . (The rest like the text of Morize.)	for 69–77 in Morize
78.	(cinq) *à* (six) (millions) *en*	à for ou en for de
79.	tu es plus habile que moi	omitted
82.	tu n'as pas tué l'Inquisiteur, on ne se défiera point de toi	omitted
83.	j'*aprêterai*	for équiperai
91.	C'était un très bon-homme que ce Cacambo	omitted
97.	Monsieur Vanderdendur *le* (maître)	omitted le added
98.	*navire*	for vaisseau
103.	*Hollandais*	for Vanderdendur
157.	*conter*	for raconter
159.	*au* (plus juste titre)	for à
160.	quelque gratification	for gratifications
168.	à démontré (*sic*) que tout est au mieux	for à demontrer son système

Chapter XX

21.	le mal moral et phisique	le mal omitted
22.	*les* (prêtres)	for mes
30.	que jettant	en omitted
30.	*ou plutôt sur ce globule*	omitted
36.	devant *qui*	for lesquels
71.	*aprit*	aperçut
72.	*un* (Espagnol)	un added
82.	et Espagnol	le omitted

Chapter XXI

6.	J'y ai parcouru	y added
16.	à ce qui	il omitted
29.	*passer*	for aller
38.	non plus que toutes	de omitted
52.	calomniateurs	omitted
59.	au port de Bordeaux	for à Bordeaux

Chapter XXII

4.	pour vendre quelques cailloux du Dorado	omitted
5.	pour son philosophe Martin et pour lui	added

6.	car il ne pouvait plus se passer de son philosophe Martin	omitted
9–13	laquelle proposa . . . *jusqu'à* mourir de la clavelée	omitted
14.	*cependant*	omitted
14.	*qu'il*	for Candide
p. 147, l. 21 to p. 149, l. 51		different text (see above)
52.	(passage) leur servent de guides, et leur font offre de services	added
52.	leur content l'histoire scandaleuse de la ville, et leur offrent des plaisirs à tout prix. Celui-ci mena d'abord Candide et Martin à la Comédie	omitted
52.	(services) Celui-ci leur apprit toutes les nouvelles. Il leur conseilla de rester longtemps à Paris; il leur conta l'histoire scandaleuse de la ville, et finit par promettre à Candide la première femme sur laquelle il jetterait les yeux aux spectacles. Candide fut sensible comme il le devait, à ses politesses, mais il lui avoua qu'il ne pouvait pas les accepter, parce qu'il avait un rendezvous à Venise avec Mlle Cunégonde. L'insinuant Périgourdin l'engagea insensiblement à conter ses aventures avec cette illustre Westphalienne. Je crois, (the rest as in the text, p. 165, line 275).	added
page 149, line 52 to page 165, line 275		omitted
287.	Candide à son réveil reçut	for reçut à son réveil
327.	par le conseil de Martin	for son conseil
330.	de chacun (environ)	for d'environ . . . chacun
333.	de chacun (trois)	for chacun de
334.	je me ferai	for ferais
337.	vous y *conduire*	for mener
page 168, line 339 to page 170, line 356		omitted
360.	Le Frère	for le Normand

Un autre chapitre XXII

12.	que le mouton	
37.	Candide dit	for répondit
37.	point *un* homme	un added
55.	on joüa une pièce nouvelle	for tragédie
59–65		omitted
	62. un mot de Chinois	omitted
	63. et cependant la scène est en Arabie	omitted
	64. (un homme) qui estime Locke et qui (the rest as in the text)	omitted
59–65	Monsieur je vous prouverai demain dans une brochure que vous avez eu tort de pleurer. La scène est en Perse, et l'auteur ne sait pas un mot de Persan. Les acteurs sont très mal cœffés et l'ouvrage est contre les bonnes mœurs. Ecoutez-moi bien. Candide ne l'écouta pas.	added (Voltaire's hand)
Page 150, line 65 to page 165, line 269		omitted
274.	(conte) selon son usage	

275. The chapter ends page 165, line 275.
cette illustre Westphalienne.
Je crois, dit l'abbé etc. *Comme dans le manuscrit de Mr Ralph* (Voltaire's hand)
p. 113[bis] est en blanc recto et verso
p. 113[ter] répète . . . tous les crimes imaginables. Line 331 to end of the chapter as in the first chapter XXII.

Chapter XXIII

8.	dit Candide	added
16.	(je sçais) *seulement*	omitted
27.	(il demanda) quel gros homme c'était	for qui était etc.
48.	tout *va* bien	for est

Chapter XXIV

4.	(caffés), *chez tous les gondoliers*	added
24.	(millions) dans *sa* poche	for ses
30.	avait très peu de (vertu) et de (bonheur)	correction by Voltaire
38.	elle (chantait)	for et
55.	à peine fut elle dans	entrée omitted
59.	(avec) *beaucoup* (d'attention)	added
76.	*Le* (médecin)	for ce
108.	*Le Théatin*	for Frère Giroflée
126.	*Le moine*	for Frère Giroflée
142.	*c'était le nom du Théatin*	added
151.	*beaucoup*	for fort
161.	*On m'a parlé*	for on parle

Chapter XXV

9.	*pas*	for point
28.	*point*	for pas
37.	(Pococuranté) en baillant	added
75.	répondit	for dit
80.	de *plus* froid	for si
81.	et *surtout* (les contes)	added
84.	*dans* un homme du monde	for dont
85.	*pour faire*	for peut faire
96.	les *antres* (?)	for astres
100.	*tout* (étonné)	for fort
101.	*fort*	for assez
106.	et	for ou
139–141	en dix livres	omitted
151.	par *des* diables	for les
152.	(personne) que je sache	added
179–80	Platon a dit il y a longtems, que les meilleurs estomacs ne sont pas ceux que rebutent tous les aliments	omitted
183.	(beautés) et en effet ne voient rien	added
191.	*seulement venus*	for venus seulement

Chapter XXVI

16.	*dit* (Cacambo)	for reprit
26.	(qui) *servait*	for versait
49.	*avaient* disparu	for ayant
50.	*demeuraient*	for demeurèrent
67.	*suivi*	for accompagné
88.	n'en ont jamais *fait*	for pu faire
89.	(à la Providence,) mais avec reconnaissance	added
94.	Ecosse	for Corse
108.	qui *les* donne	for le

Chapter XXVII

7.	*dit*	for disait
9.	*de* ces six	for dans ces six
14–22	Ces 8 lignes n'existaient pas dans le manuscrit. De "Mais, dit Candide" jusqu'à "ne mérite pas notre attention."	omitted
29.	*répondit Cacambo*	added in the margin in the Voltaire's hand
31.	qui a *peu*	très omitted
33.	*six* écus	for trois
41.	Figueroa	for Figueora
44.	en pirate *Turc*	added
45–47	le Pirate *to* Scutari	omitted
48.	Ce pauvre Prince	pauvre added
60.	je ne sçais pas	pas added
61.	aurait pu	peser omitted
104.	(Vous les aurez, Mr) repartit Candide	added
114.	ma sœur	chère omitted
118.	s'embrassaient tous, *ils parlaient tous* à la fois	ils parlaient tous omitted
120.	qui en valait bien	for de la valeur de
120.	et qui lui jura par Abraham, qu'il n'en pouvait donner davantage	omitted

Chapter XXVIII

6.	*à* travers	for au
22.	*sur* la plante	for sous
25.	d'un *pauvre* souverain	pauvre added in Voltaire's hand
27.	(mais) vous	added
41.	elle fut mal nouée	added
42.	un si *horrible* cri	for grand
46.	étendu sur la table	for sur la table étendu
86.	*mon cher* Pangloss	added
92.	correction of Voltaire: . . . Leibnitz ne pouvait (pour pouvant) pas avoir tort, et l'harmonie préétablie est d'ailleurs (the rest as in the text)	

Chapter XXIX

4.	continuaient *le récit de* (Voltaire's hand, added) leurs aventures	for contaient leurs aventures
6.	et *sur* les causes	added
27.	qu'il allait *enfin*	added

Chapter XXX

3.	*nulle* envie	for aucune
16.	*et n'en* dit rien	for on n'en
17.	*d'attraper ainsi*	added
21.	*et* le prudent	added
32.	Pour Martin, *comme*	added
36.	passer souvent	for souvent passer
37.	chargés de têtes de Bachas	d'Effendis, Cadis omitted
38.	(cadis) qu'on envoyait en exil à Lemnos, à Mitilène, à Erzerum	omitted
	qu'on allait présenter à sa Hautesse	added
39–43	On voyait venir *to* Sublime Porte	omitted
45.	osa leur dire un jour	for un jour leur dire
46.	vaut le mieux	for est le pire
50.	*vous avez* tous	for nous avons tous
101.	*pendant quelques heures*	omitted
	parce que c'était l'histoire du jour	added
111.	mais jamais je ne m'informe	for mais je ne m'informe jamais
124.	*dix*	for vingt
125.	avec *ma fille*	for mes enfans
130.	*j'ai eu*	for nous avons eu
137.	Athalia *assassinée* (Voltaire's hand, added) par Joïda, et (added, V's hand) le fils de Joïda assassiné par Joas	
156.	Tapissier (changed by Voltaire to menuisier)	
163.	si vous n'aviez pas été en Amérique	for couru l'Amérique
165.	perdu tous vos moutons du bon pays d'Eldorado	omitted
	emporté quelques diamants du bon pays d'Eldorado	added

It is clear from these variants that the manuscript will add much to our knowledge of the original text of *Candide*. It will throw additional light upon the composition of the conte, and even give us some clue as to the moment of composition. A striking omission in the manuscript version, for instance, is the episode of the slave at Surinam. That, as well as other omissions, will need careful study. I am undertaking to make this study at the present time. At its conclusion, a microfilm of the La Vallière manuscript will be deposited in the Library of the American Philosophical Society.

THEORETICAL CONSIDERATION OF CYCLIC PROCESSES IN DORYLINE ANTS[1]

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(*Read November 10, 1955*)

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INTRODUCTION

PREDATORY expeditions and colony movements are traditionally well known for the ant subfamily Dorylinae.[2] But until recently, changes of nest site in the colonies of these ants were described as sporadic and irregular, somehow enforced on a nutritive basis. Both Heape (1931) and Fraenkel (1932), reviewing the earlier evidence, classified the driver and army ants as irregular emigrants rather than migrants, as the colonies were presumed to undertake changes of nesting site only when booty had been cleared from an occupied area. This conception proves to be wrong (Schneirla, 1946).

Recent investigations (Schneirla, 1933, 1938, 1949; Raignier and Van Boven, 1955) show that emigrations in these ants occur in periodicities characteristic of species, through other than nutritive causes. My own investigations have centered around two species in the tropical American genus *Eciton*, known as "army ants." The functional pattern of these species, in all probability the most specialized in the subfamily, will be considered first, and a theory formulated which may throw light on conditions in other dorylines.

CYCLIC FUNCTION IN THE EPIGAEIC ECITONS

THE NOMAD-STATARY PATTERN

Contrasting Activity Phases

The species *Eciton hamatum* and *E. burchelli* are among the few in the subfamily which may be termed *epigaeic*, in that they have evolved a dominantly terrestrial way of life. Their nesting, raiding, and emigrating occur mainly on or above the surface, in contrast to the more subterranean

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Evidence of great value to this investigation has been made available by Dr. Harold Hagan, Professor Emeritus of Biology, City College of New York, and by Dr. Roy Whelden, Haskins Laboratory, Union College, from histological and cytological studies carried out by them on preserved Eciton queens and other material collected by us in the field.

It is also a pleasure to acknowledge the efficient assistance of Drs. Eleanor Lappano, now Research Assistant at the Rockefeller Institute, New York, and Dr. John Tafuri, now Assistant Professor of Biology at Xavier College, Cincinnati, Ohio, particularly in the study of larval development in *Eciton*.

[2] In the cosmopolitan ant subfamily Dorylinae (see Forel, 1891; Emery, 1885, 1910; Wheeler, 1910, 1922) are included two tribes of particular interest to this paper, tr. *Dorylini* Forel of the Old World and tr. *Ecitonini* Forel of the New World. In a recent taxonomic survey of the *Ecitonini*, Borgmeier (1955) has raised groups formerly designated as subgenera to generic rank as follows: genus *Eciton* (= subgenus *Eciton s.str.*), genus *Nomamyrmex* (*g.nov.*), genus *Labidus* (= subgenus (*E.*) *Labidus*) and genus *Neivamyrmex* (= subgenus (*E.*) *Acamatus*).

TABLE 1

DURATION OF PHASES (ALL-WORKER BROODS ONLY) IN THE FUNCTIONAL CYCLES OF TWO *Eciton* SPECIES OBSERVED AT DIFFERENT TIMES OF YEAR (1932–1952)

Species	*E. hamatum*								*E. burchelli*							
Season	Rainy				Dry				Rainy				Dry			
Activity phase	Nomadic		Statary		Nomadic		Statary		Nomadic		Statary		Nomadic		Statary	
	Cases	Days	Cases	Days	Cases	Days	Cases	Days	Cases	Days	Cases	Days	Cases	Days	Cases	Days
	5	16	1	18	4	16	1	18	1	11	1	19	1	13	2	19
							2	19	1	12					6	20
	6	17	3	19	7	17	11	20	1	13	1	21	1	15	7	21
							11	21					2	16	2	22
	4	18	9	20	2	18	1	22	1	15	2	22	2	17		
Average	16.9		19.6		16.8		20.3		12.8		21		15.7		20.5	
Range	16–18		19–20		16–18		18–22		11–15		19–22		13–17		19–22	

patterns otherwise predominant in the subfamily. In the tropics and subtropics of the world are hundreds of other species all more or less strongly hypogaeic, or subterranean, especially in their nesting activities, some largely or entirely subterranean in their predatory operations as well.

Eciton hamatum and *burchelli* present a striking regularity in all of their principal colony operations, clearly related in its evolutionary background to the physical conditions of surface life. Their functional pattern as a whole is cyclic, its predictable periodicity based upon rhythmic processes to be considered. Colony functions in these species center around two well-marked repetitive activity phases, as schematized in figure 1. There is first a highly active phase, the *nomadic*, in which successive large daily raids occur, each ending in an emigration at the day's end. Each successive temporary nest or bivouac established in this phase is on or above the surface of the forest floor and largely exposed except for a natural ceiling such as the undersurface of a log from which it hangs to the ground (Schneirla *et al.*, 1954).

There follows an interval of greatly reduced activity and relatively sessile existence in the colony, the *statary* phase, in which raids are much smaller, and on some days absent. The colony now remains at the same nesting site, usually in a well-sheltered place as inside a hollow tree or log, without emigrating. In these species, the behavioral and functional properties of this phase are clearly distinguished from those of the nomadic phase.

In *Eciton* colonies these two phases recur in regular alternation throughout the year. This fact has been established both through long-continued studies of single colonies at various times of year and through the comparative study of numerous colonies over shorter periods of time (Schneirla, 1949). As table 1 shows, the phase durations are highly predictable according to species. The average duration of the nomadic phase is seventeen days for *hamatum*, with a year-around range of just three days, but for *burchelli* this phase is shorter and more variable. No seasonal difference is indicated for *hamatum*, but for *burchelli* this phase tends to be longer in the dry season. The two species are more alike in the duration of the statary phase, which is uniformly longer in both than is the nomadic phase.

Colony Behavior and Brood Condition

Predictability of phase durations in these species indicates a basis in regular events affecting the colonies. Investigation shows that in all colonies each of these phases begins and ends in close correspondence with certain major changes in the condition of the great broods always present in the colonies (*op. cit.*). For most of the year, only all-worker broods are present; however, the relationship holds also for the exceptional sexual brood (Schneirla, 1948; Schneirla and Brown, 1950). Evidence on colony behavior and brood development demonstrates (Schneirla, 1938, 1949) that

not only the regular colony functional cycle but survival of the colony itself in these ants is based upon the concurrence of these conditions.

Eciton all-worker broods occur in distinctive successive generations, each with 50,000 individuals or more in *E. hamatum*, 120,000 or more in *burchelli*. As figure 1 shows, at the start of each nomadic phase a brood of mature pupae emerges

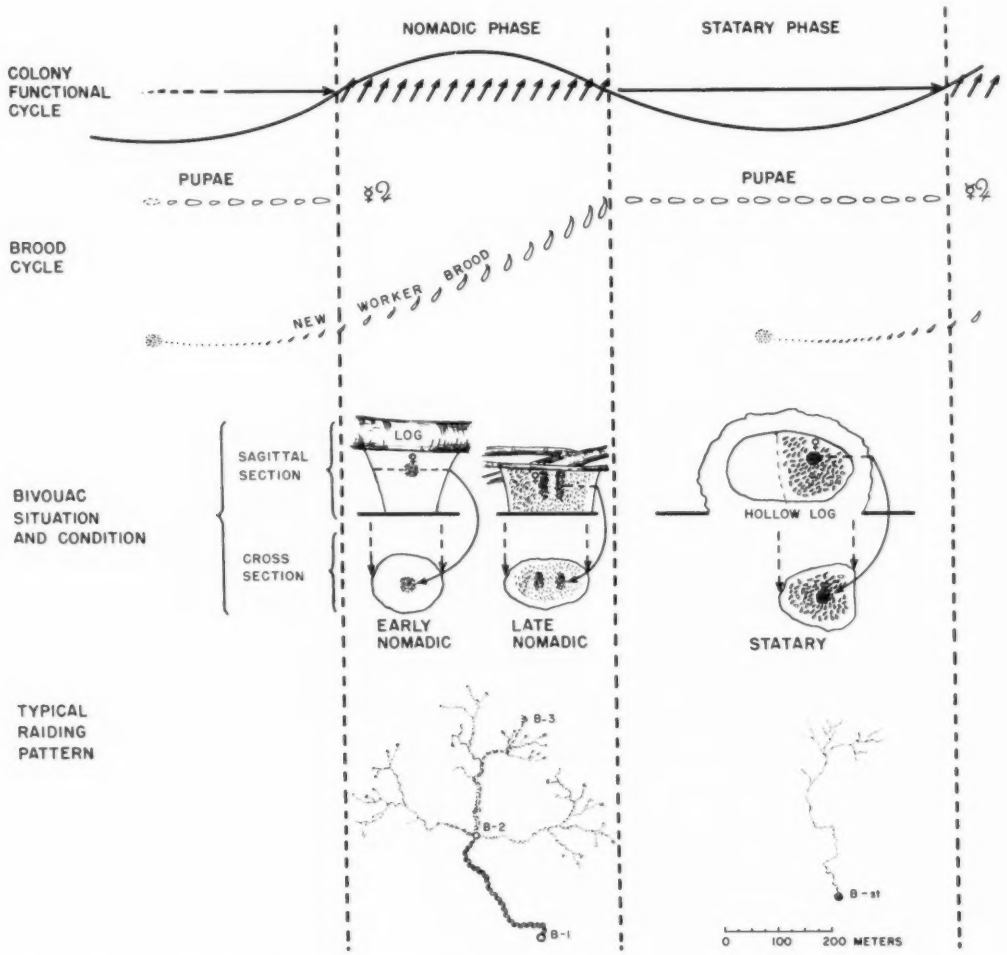

FIG. 1. Schema representing concurrent events in the nomadic and statary phases of the Eciton functional cycle, based on *Eciton hamatum*.

Colony functional cycle.—Crest of sine wave, nomadic phase: arrows represent large daily raids, ending in nightly emigrations. Trough of sine wave, statary phase: line represents reduced raiding, absence of emigration.

Brood cycle.—One complete brood series is represented, from *left*—eggs, larvae, and enclosed pre-pupal and pupal stages, to newly emerged callow workers at *right*.

Bivouac.—At *left*, exposed bivouac cluster of the nomadic phase, suggesting principal changes in brood distribution: at *right*, sheltered bivouac of the statary phase, suggesting new brood as egg mass centered below queen, advanced brood as enclosed pupae

Raiding pattern.—*Left*, three-system column raid of the nomadic phase, developed from the bivouac at B-2; previous night's emigration line, B-1 to B-2; emigration line after current raid ends, B-2 to B-3. *Right*, single-system column raid of the statary phase, from the fixed bivouac site *B-st*.

TABLE 2

CONCURRENT DAILY TRAFFIC COUNTS OF RAIDS IN THREE COLONIES OF *E. hamatum*
(Records taken near bivouac between 10:30 A.M. and noon)

Colony	Phase	Number of days	Outgoing traffic (Ants/min.)		Incoming traffic (Ants/min.)		Incoming, laden (Ants/min.)	
			Range	Average	Range	Average	Range	Average
'52 H-C†	Nomadic	12	65–242	130	27–171	106	27–166	80
	Statary*	11	0–143	58	0–147	43	0– 86	27
'52 H-O	Nomadic	11	26–122	60	14– 80	50	2– 60	27
	Statary*	6	0– 58	15	0– 28	12	0– 26	8
'49 H-35	Nomadic	8	24–109	61	19–146	67	15–126	55
	Statary*	17	0– 92	28	0– 74	26	0– 54	20

† Colony '52 H-C was much larger than either of these other two colonies.
* Occasional statary days without raiding. (See table 4.)

from cocoons as young adults, and during this phase a further brood passes through its larval stage, reaching larval maturity at the end of the phase. As this current brood undergoes its prepupal and pupal development (enclosed within cocoons) in the following statary phase, a new brood appears as eggs laid midway in the phase. New broods are produced at intervals of 35–37 days in *hamatum*, 32–37 days in *burchelli*, the durations of the cycle in the two species, respectively. These events continue, year around, through the life of the colony without any break in the repetition of the cyclic changes.

Colony function reaches its highest level of intensity in the nomadic phase when active brood stages are present, its lowest in the statary phase when the brood is relatively quiescent. This difference in activity level is most prominently expressed in terms of a difference in the daily mass forays or raids. Raiding, carried out on chemical trails developed each day, differs radically in strength in the two phases. In *E. hamatum*, the typical nomadic-phase pattern of three large tree-like systems of raiding trails (with terminal groups of pillaging workers) contrasts sharply with the single trail system usual in the statary phase (fig. 1). Systematic traffic counts for three colonies of this species, taken daily, gave the results in table 2. Within the ninety minutes before noon, when raiding traffic as a rule reaches its peak in the statary phase, both outgoing and incoming traffic are more than twice as great during the nomadic phase as in the statary phase. The estimated ratio of three to one seems closer to actuality, as nomadic-phase raids reach their peak output before mid-morning as a rule; also, days without raids are not uncommon in the statary phase, especially in the dry season.

As mentioned, both Heape (1931) and Fraenkel (1932) relegated the doryline ants to the class of sporadic emigrants rather than migrants, on the assumption of Vosseler (1905) that colony movements somehow occur in response to exhaustion of food in the nesting locality. This assumption is contradicted by the evidence for Eciton raiding in relation to the occurrence of emigration (Schneirla, 1938, 1944*b*, 1945).[3] Raignier and Van Boven (1955) reached a similar conclusion from their study of African dorylines. Whatever role local food supply may have played in the evolution of nomadism in these ants, the determination of emigrations in the existing behavioral system has a different basis.

[3] There are good reasons for considering their pattern of cyclic series of displacements, alternating with resting phases, as a case of migration (Schneirla, 1945). One important reason is that the colony movements have their basis in reproductive processes, an important condition of migration in general (Marshall, 1936). The separate nightly bivouac-change movements may be termed *emigrations* and regarded as contributing to *a migration:* the total displacement involved in the series of movements of one nomadic phase. Through these successive emigrations the colony regularly changes its ecological situation from that characteristic of the nomadic phase to that of the statary phase (Schneirla *et al.*, 1954), a reversal somewhat comparable to the vertical migrations whereby certain tropical birds in mountainous areas reverse their ecological situation with seasonal regularity.

Reciprocal Stimulative Processes in Social Function

The fact is that in these *Eciton* species an emigration can occur only as an outcome of a large raid, and that statary-phase raids are insufficiently developed to produce this result (Schneirla, 1938, 1944*b*). The differential is provided by stimulation from active brood. First, callow workers are very attractive and excitatory to adults. From the moment these new workers emerge from their cocoons they are feverishly licked and groomed, and their almost incessant movements are powerfully stimulative to the older workers of the colony. Second, the more advanced larvae are very attractive and excitatory to workers, who lick, stroke, and handle them incessantly. Adult workers evidently derive a variety of tactual and chemotactic stimuli as well as secretory products from active brood at both of these stages, which always occur in the nomadic phase of colony function. In contrast, in the statary phase the brood, cocoon-enclosed and passing through the quiescent prepupal and pupal stages, lacks potency in this respect. The cocoons, held in place or heaped in the bivouac interior, often seem to have a quieting effect upon the workers. Laboratory tests show that workers from a nomadic colony are more excitable and reactive than are those from a statary colony.

Excitatory effects based on individual associations with brood usually do not stop with the stimulated worker herself but are transmitted widely through the colony, permutated and increased through a variety of worker interactions. Through interindividual stimulative relations normal to colony communication, colony excitation is maintained at a high level, as long as an active brood is present. Active brood (callows, larvae, or both) is the necessary energizing source of high excitation in a nomadic colony, and brood excitation may be broadly represented as a massive energizing effect essential to nomadic colony functions such as raiding and emigration. In this sense the stimulative effects (tactual and chemotactic) are expressible as a summated quantitative value differing according to brood condition at each point in the functional period. The results of our investigations bearing upon these considerations are expressed as an empirical curve in figure 2, in which each of the postulated intra-colony energizing factors is represented quantitatively in its estimated contribution at different stages of the functional cycle, in relation to the theoretical level of arousal essential for emigration, or the "emigration threshold."

This view of the stimulative process is based upon observational and laboratory studies with adults in relation to brood at various stages during the two phases of the cycle. Even casual observation shows that the stimulative processes are not always unilateral, but are often reciprocal as between active brood and workers, and at certain times even as between enclosed brood and workers. In this general respect the Ecitons resemble other ants, for which Wheeler (1928) characterized the reciprocal relationship as "trophallaxis," or the exchange of food. Processes characterized by this term were held by Wheeler, on general consideration, as basic to colony organization and unity in the social insects.

The army ants offer in detail a striking support of the *trophallaxis* theory of colony function and unity, *if* the theory is extended beyond the specific implications of Wheeler's concept (Schneirla, 1952; LeMasne, 1953). True, the transfer of nutrient substances and other organic products is common in the Ecitons (Wheeler and Bailey, 1920; Wheeler, 1928): excited workers dump booty on larvae or larvae on booty, workers obtain cuticular secretions and the like through licking larvae or callows, and so on. These biochemical gains are no doubt contributive to and essential to brood development as well as to colony health and normal function. However, adult-brood relationships go beyond nutritive gains as such to include a variety of stimulative effects in the olfactory, gustatory, and tactual modalities. Workers become excited when passing close to larvae (even when separated by a gauze screen), and larvae also when workers are close, indicating olfactory arousal. A comparable arousal on a tactual basis is evidenced by the manner in which artificial stimulation of larvae to their characteristic anterior writhing motions stirs nearby adults to begin or to increase action. The incidental touching of larvae by passing workers has equivalent effects.

The definition of "trophallaxis" consequently must be extended from the effects of exchange of nutrient as such to the many and varied ways in which specific stimulation independent of nutrient gains arouses or increases action or serves to facilitate physiological processes in the colony. The dissemination of stimulative effects is indispensable for the normal function, organization, and unity of the colony. In these processes, nutrient gains although important constitute only a part of

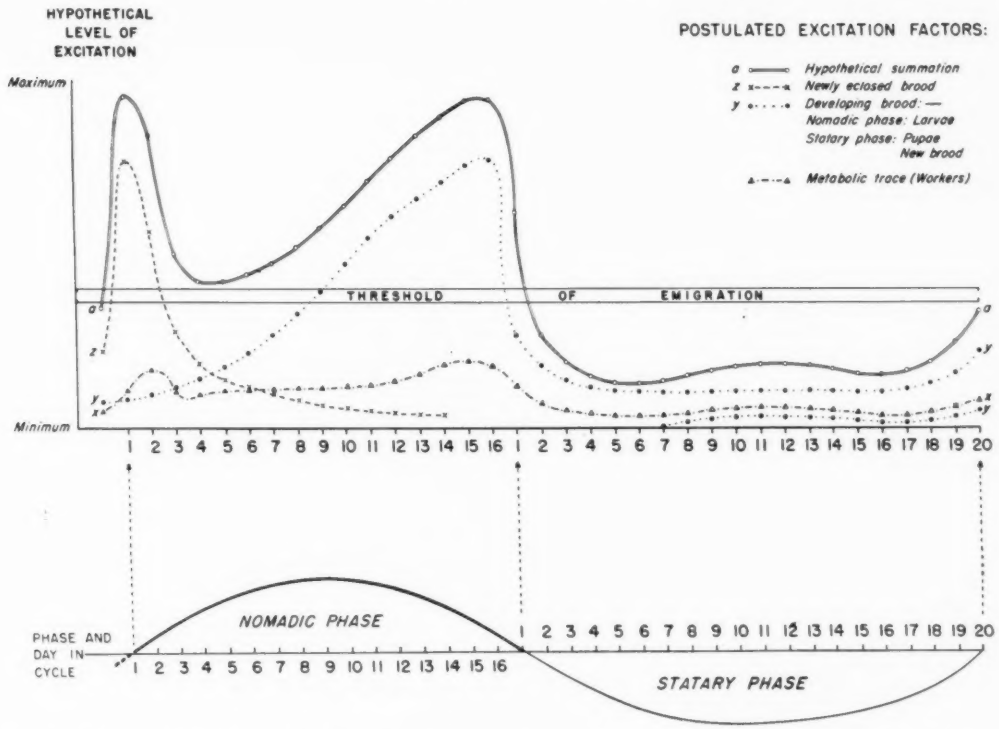
HYPOTHETICAL LEVEL OF EXCITATION
Maximum
Minimum
POSTULATED EXCITATION FACTORS:
a Hypothetical summation
z Newly eclosed brood
y Developing brood: — Nomadic phase: Larvae Statary phase: Pupae New brood
Metabolic trace (Workers)
THRESHOLD OF EMIGRATION
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PHASE AND DAY IN CYCLE
NOMADIC PHASE
STATARY PHASE

FIG. 2. Schema of the principal social-excitation factors (*above*) underlying the Eciton functional cycle (sine curve *below*). Excitation-factor curve in upper figure represents empirically based judgments of the total stimulative effects of the respective factors at successive stages in the cycle (*see text*). The level of colony excitation as represented is based upon both observed and quantified variations in the raiding output.

the functional pattern, a sustaining by-product in a sense, as concerns arousal and maintenance at high intensity of large-scale worker functions.

Our findings indicate that for the extra-bivouac functions of raiding and emigration, the aggregate of stimulative effects from brood may be considered the major factor determining the level of colony behavior at any point in the cycle. The brood-energizing factor is therefore held to be the *necessary* factor for nomadic behavior and for propagation of the cyclic pattern itself (Schneirla, 1938, 1952). In these terms, normal behavior and function in the terrestrial Eciton colony may now be examined in further detail.

ANALYSIS OF THE ECITON NOMAD-STATARY CYCLE

Brood-stimulative Factors in Nomadism

The callow-excitation factor initiating nomadism:

The shift from nomadic to statary function is a striking one in both *E. hamatum* and *burchelli*. In a relatively lethargic condition one day, the colony next day stages a large raid and emigrates after dusk. This is the day on which as a rule removal from cocoons of all of the mature pupal brood is accomplished in *E. hamatum*, usually the major part but not all of the brood in *E. burchelli*. The bivouac then becomes the scene of intense and growing excitement. The newly emerged callow workers are persistently active, rushing about in an erratic and "nervous" manner, feeding voraciously in the hours following eclosion. The workers are very responsive to these young adults, often running up and dropping morsels of booty among them (Wheeler and Bailey, 1920), stroking and licking their body surfaces. The level of general excitement in the population rises greatly over that of the preceding days, as is indicated for example by a noticeably increased responsiveness of the workers at dawn. This external stimulus, reaching a community already well aroused, ex-

cites the workers into a vigorous and rapidly growing exodus (Schneirla, 1938, 1940). The resulting raid, well above the statary level in excitement, numbers of participants, and in scope and complexity, exceeds the threshold essential for an emigration to occur as sequel.

The eclosion of a mature pupal brood, by releasing into the colony a relatively sudden, massive social stimulation, initiates a new nomadic phase in previously statary colonies of both *E. hamatum* (Schneirla, 1938) and *E. burchelli* (Schneirla, 1944*b*). The one difference is a secondary one already mentioned, namely, that in *E. hamatum* the pupal eclosion is nearly always completed throughout the brood on the first nomadic day, whereas in *burchelli* nomadism commonly begins with as much as one-third of the pupal brood (always the smallest members) still enclosed in cocoons. This difference suggests that the threshold of colony arousal essential to nomadic function may be expressed in terms of a critical ratio between the population of active brood and the population of adult workers.[4]

Although the nomadic phase invariably begins in an explosive manner in these species, as figure 2 indicates, the excitatory callow-adult relationship responsible for the change persists at high intensity only for a few days. But in these epigaeic army ants, the nomadic phase persists well beyond this time to a predictable end. For its continuation, new causal agents seem necessary.

As may be seen in table 1, the nomadic phase normally continues to a duration of 16–18 days in *E. hamatum* and 12–16 days in *E. burchelli*. But persistence of the nomadic condition through these species-typical intervals in the epigaeic Ecitons cannot be due to the effect of the callow-stimulative factor which initiates the phase. For in about 5 days after the phase begins, the callows have subsided markedly in the degree of excitement and variability of their behavior and in voraciousness; they now behave more and more like adult workers. As their integument darkens during this interval, the callows become more difficult to distinguish from adult workers, both in appearance and in behavior. Laboratory tests show that their stimulative effect upon adults tends to decrease sharply after the second post-eclosion day, and has reached a minimum after the fifth day (*cf.* fig. 2).

Excitatory factors in the transitional stage:

But the colony does not therefore lapse to the low statary level of general excitation, either in extra-bivouac or in intra-bivouac activities. Worker populations maintain a condition of increased excitement even in the absence of further brood-excitation factors. Colonies in the field continue their initial nomadic excitement, although decreasingly, after brood other than callow types has been largely removed. Workers from nomadic colonies at this stage, held in laboratory nests without brood, remain more active for some days than groups of the same size taken from statary colonies.

On such grounds, a "metabolic trace" factor may be postulated in the worker population (fig. 2), persisting from the stage of intense callow excitation.[5] This condition, presumably a survival from the initial burst of brood-stimulative and associated nutritive gains, serves to prevent the worker population from lapsing to a state of low responsiveness and activity as external stimulation from callows falls sharply. It may be postulated as essential to the continuation of nomadism in terrestrial Eciton colonies, although not as the main factor.

Larval-excitation factor continuing nomadism:

In contrast to the more hypogaeic dorylines, in the epigaeic Ecitons the larval brood now begins to function as a major source of stimulation promoting nomadism. In *E. hamatum* and *burchelli*,

[4] Both brood and adult population are much larger in *burchelli* colonies than in *hamatum*. The difference may depend upon a disproportionately greater communicative extension of the brood-excitation effect in a larger colony population than in a smaller one. This assumption is supported by the fact that in the rare cases of *E. hamatum* becoming nomadic prior to complete eclosion of the mature pupal brood, colonies of maximal size for the species are involved. Significantly, in the African driver ants, Raignier and Van Boven (1955) find that statary intervals are broken by emigration before more than a minor part of the great nymphal brood of the colony (always the largest individuals) is sufficiently mature for independent locomotion.

[5] Such a factor seems frequently involved in insect behavior. As an example, Long (1955) found that mass feeding episodes in the caterpillars of *Pieris brassicae* and the extra stimulation furnished through summations of interindividual contacts in caterpillars of *Plusia gamma* induced a higher level of activity which could persist in solitary specimens. Comparably, through physiological trace effects of summated stimulative and trophic experiences in the colony situation, Eciton workers from a nomadic colony, when stimulus-tested individually or collectively in standard ways, prove more reactive than workers from a statary colony.

a new brood is produced roughly at five-week intervals, from eggs laid midway in the statary phase of the preceding cycle (see fig. 1). Figure 2 suggests how this brood enters as an essential factor in colony function. When nomadism begins, these larvae are diminutive, and as an aggregate (as compared with the callow brood) can have only a relatively minor trophallactic effect. At this stage the young brood is concentrated in a single mass near the center of the bivouac (fig. 1). Composed of eggs and micro-larvae, this brood evidently then exerts a low stimulative effect on the colony, not communicated widely through the bivouac by the minim workers largely engaged in handling it.

At the fourth or fifth nomadic day as figure 2 indicates, the stimulative effect of the larval brood has begun to accelerate. Its central position in the bivouac is now more extended, with larger larvae more marginal and attended by intermediate workers as well as minors. It is observed that larvae down into the intermediate sizes have begun to feed, a result paralleled by the histological finding (Lappano, 1955; Tafuri, 1956) that in brood samples at the fifth nomadic day, these larvae as well as the larger castes have functional salivary glands, still lacking in the smaller larvae (see table 3). Test groups of workers in the laboratory given larvae from a colony in its *fifth* nomadic day become much more active than groups of equal size given equivalent numbers of larvae from a colony in its *second* nomadic day. But at this stage, when the larval brood has just begun to accelerate in growth rate, the cumulative excitatory effect of this brood upon workers is still relatively low.

In the interval between the second and sixth nomadic days, there are indications of a fall in the vigor of colony functions as in raiding. Nomadism then is most sensitively affected by artificial brood reductions or natural causes inhibiting colony functions (Schneirla and Brown, 1950). In the dry season, when environmental depressive effects are maximal, 69 days recorded in the continuous nomadic sequences of 9 colonies of *E. burchelli* involved subnormal raiding and failure to emigrate on 9 days, of which 7 were in the first 6 days of the nomadic phase, and 4 on the third day. A comparable susceptibility is seen in *E. hamatum* only when broods are reduced, as occurs naturally at colony division when callow and larval broods are divided between two daughter colonies (Schneirla, 1956). In the two daughter colonies of *'48 H-27*, the first 9 days of a nomadic

TABLE 3

SUMMARY OF LAPPANO'S (1955) RESULTS ON DEVELOPMENTAL CHARACTERISTICS OF LABIAL GLANDS AND TIME OF APPEARANCE IN THE ALL-WORKER LARVAL BROOD OF *Eciton burchelli*

Larval size category	Proliferation of posterior, basophilic portion*	Cells of posterior glandular portion increase in size, degree of vacuolization*	Lumen blocked posteriorly, absent anteriorly (2nd abdominal segment)*	Dense cytoplasm in posterior cuboidal cells; vacuolization irregular**	Disintegration in midsection proceeds posteriorly; products fill lumen**	Accumulation of acidophilic materials in lumen progresses anteriorly**
Largest (potential major workers)	Last statary, 1st nomadic day	3d nomadic day	5th nomadic day	8th nomadic day	10th nomadic day	10th nomadic day
Middle sizes (potential intermediate workers)	3d nomadic day	5th nomadic day	7th nomadic day	.....	11th nomadic day	11th nomadic day
Smallest (potential workers)	Mainly by 6th nomadic day	7th nomadic day	8th nomadic day	10th nomadic day	13th (last) nomadic day	13th (last) nomadic day

* Changes believed to indicate onset of capacity for salivary secretion in gland. These time values correspond closely to those established behaviorally for the onset of feeding in larvae: first in the largest, last in the smallest individuals of the series.

** Changes believed to indicate onset of spin-substance secretion in gland. Only after disintegration occurs in the blocked midregion of the gland can the acidophilic material (probable spinning fluid) pass anteriorly so that spinning may begin. Chronology of histological change here also corresponds in general to times at which spinning is observed to begin in the different larvae.

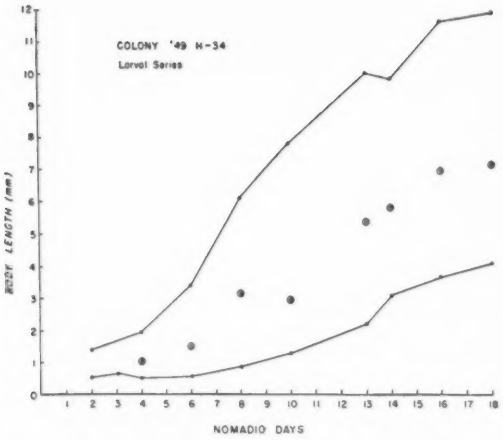

FIG. 3. Increase in body length in the larval brood of a colony of *Eciton hamatum* sampled (N = 50–100) at intervals through a nomadic phase. *Upper curve*, body length in *mm.* of largest larvae (potential workers major) in the successive samples; *lower curve*, body length in *mm.* of smallest larvae (potential workers minima) in the successive samples; intermediate points, average for each sample.

phase were recorded before the study had to terminate. There were 4 days with subnormal raids and no emigration, all between days 2 and 5 of the phase, and each colony failed to raid or move on the third day; thereafter, in each daughter colony, function increased steadily in vigor to the normal level.

The interpretation is that normally, between the second and sixth nomadic days, the worker population falls from its initial high level of excitement to the lowest condition of the phase because the excitatory effect of the callow brood has fallen sharply and that of the larval brood has only begun to rise. For this interval, the summated effect of three indicated brood-excitatory factors is postulated for the maintenance of nomadic function in the colony. Although each of the three factors then seems to be at a low point in its strength, as figure 2 suggests, their joint effect is normally sufficient to raise colony excitation above the threshold essential for nomadic function.

But after the first few nomadic days the larval brood exerts a clearly increasing stimulative effect upon the adult population, evidently commensurate with its acceleration in growth (fig. 3). This brood occupies an expanding central zone in the bivouac (fig. 1), its larger members farther out toward the margin, its smaller members inward, in proportion to size (Schneirla *et al.*, 1954). As the phase wears on past its midpoint, more and more of the intermediate and larger workers become directly involved with the brood: licking, stroking or holding the larvae individually in the bivouac, feeding them, or carrying them in the emigration. As this brood progresses toward maturity, the intensity of nomadic function, as indicated by increases in the vigor of raiding and extent of emigration, mounts steadily to a climax.

Review: stimulative factors supporting nomadism:

To take stock, figure 2 represents the estimated gross effects of the three principal social-stimulative factors postulated as essential for nomadic function in the epigaeic army ants. Factor 1, the *callow-brood effect*, is held to initiate the phase. Factor 2, the *metabolic traces* in the workers from excitatory and nutritive effects of active brood, is given a secondary role, yet evidently a critical one when other stimulative influences are at their lowest in the phase. In the epigaeic Ecitons factor 3, the *larval stimulative factor*, is at first a minor agent but increases in its excitatory effect roughly in relation to developmental status of the brood. It is this factor, replacing the callow-brood effect as major stimulative agent, that is held responsible for sustaining colony function at a high level through a nomadic phase of predictable duration.

This phase and its termination as a sustained interval of nomadism seem unique to the Ecitons. In the last few days of the phase, larvae feed decreasingly as maturity approaches and spinning begins, first in the largest individuals and last in the smallest. Paralleling this behavior change, Lappano's histological studies summarized in table 3 reveal in *Eciton* larvae a progressive atrophy of the basophilic salivary gland tissue associated with feeding, along with an increase in acidophilic secretory substance associated with spinning. These changes are readily identified at this time, the former beginning anteriorly in the tubular labial-gland complex, the latter beginning posteriorly and progressing anteriorly until it has displaced the atrophied salivary tissue. These changes, also, are identified first in the largest larvae or potential workers major, last in the smallest or potential workers minima. But, as mentioned, *although feeding drops off from the largest to the smallest members of the brood as spinning begins, the total excitatory effect of this*

TABLE 4

FREQUENCY OF RAIDING ON THE CORRESPONDING DAYS OF CONSECUTIVE STATARY PHASE SERIES IN TWO *Eciton* COLONIES OF DIFFERENT SPECIES (Schneirla, 1949)

E. hamatum, colony '46 H-B				*E. burchelli*, colony '46 B-I			
Sum for three successive statary phases				Sum for four successive statary phases			
Statary days	Days observed	Raids* observed	% days of raiding	Statary days	Days observed	Raids† observed	% days of raiding
1– 2	6	6	100	1– 3	11	11	100
3– 4	6	3	50				
5– 6	5	1	20	4– 6	12	8	66
7– 8	3	0	0				
9–10	4	2	50	7– 9	8	2	25
11–12	4	1	25				
13–14	4	1	25	10–12	9	4	44
15–16	5	4	80				
17–18	4	3	75	13–15	6	2	33
				16–18	8	5	62
19–20	5	5	100	19–21	12	12	100

* Raids weak: days 5, 10, 16 (one each). Raid late in starting: days 10, 16 (one each). Raid started *artificially* after 2 P.M.: days 16, 17 (one each).

† Exceptionally weak: day 10 (2 raids). Raid morning only: days 10, 12 (one each). Raid afternoon only: days 6, 7, 15, 18 (one each).

brood on workers mounts steadily to the time when spinning predominates in the brood.

Then, rather precisely when most of the larvae have become enclosed in their first filmy envelopes, there is an abrupt reduction in worker activities outside the nest, marked by smaller raids (table 2) and no emigration. The nomadic phase then is ended through an abrupt fall in the level of brood-stimulative effects. On one day the colony is nomadic; next day, with the brood enclosed and much less excitatory to workers, the colony has become statary.

The Statary Phase as a Specific Behavioral Condition

The statary phase may be viewed as a condition in which the worker population has only a minimal stimulation from the brood. As long as the advanced brood is enclosed, with little more than the behavioral processes of the worker population alone to stimulate large-scale activities outside the bivouac, the threshold of raiding development essential for emigration is then never reached (fig. 2). Consequently, the statary phase normally persists until the enclosed brood has reached pupal maturity and eclosion, when a callow excitation effect of high intensity is introduced, adequate to initiate a new nomadic phase.

Eciton colonies are restricted to a low level of activity in their statary phases; however, behavior is by no means constant throughout. An appreciable variability is suggested by table 4, in which are given the frequencies of raiding through consecutive statary phases in two *Eciton* colonies of different species. In both colonies, raids occurred daily in the first few and the last few days of the phase, but in the intervening days were reduced in frequency. Furthermore, parallel differences are found in the *vigor* of raiding, with the strongest statary forays almost always those of the first few and the last few days of the phase.

The greater frequency and strength of raids in the initial statary days may be attributed to the fact that the mature larval brood continues its cocoon-spinning activities for a few days after the statary phase has begun. Then, as laboratory tests show, the movements of the larvae within their cases excite the adult workers to greater ac-

tivity, both in responding to the larvae and in general colony function. Significantly, spinning always lasts a day or two longer in *E. burchelli* than in *E. hamatum*, and, as table 4 indicates, a corresponding difference is found in the raiding.

A comparable effect of the brood on colony activity occurs in the last few days of the statary phase, when the pupal brood is nearly mature. Then, starting with the largest members, pigmentation begins and reflex activities of increasing intensity are noted, first in antennal funiculi and leg tarsae, then in the trunk as well. Tests show that not only tactual stimulation, but chemotactic effects also, are available to workers through these changes. In fact, the actual behavioral processes through which mature pupae are finally removed from their cocoons by workers arise through such stimuli, which cause the adults to pick up the cocoons, carry them about and tug at them with some excitement, thereby starting the openings which pupal struggles aid in enlarging (Schneirla, 1934).

The described variations in colony function in the course of a statary phase, attributable to relatively slight variations in the stimulative effect of an enclosed brood upon an adult population, further emphasize the need to reinterpret "trophallaxis" as *reciprocal stimulative processes*. It may be concluded that the major brood-stimulative factors we have found critical for setting off a nomadic phase (the callow-excitation effect) and for maintaining this phase to its conclusion (the larval-excitation effect) owe their energizing force not to what exchanges of nutrient substances may be involved but to the efficacy of stimulative processes affecting the level of colony behavior. Nutrient exchange may be considered a by-product, facilitative when present but not necessary to the brood-aroused communicative processes permutated into higher intensities in colony behavior.

Role of the Queen in the Eciton Cycle

Regularity of reproductive processes:

Behind these events of the *Eciton* functional cycle stands the queen as the source of the massive broods appearing at regular intervals. As she is solely responsible for the egg series of each new brood, and as she produces these egg series at regular intervals, she is in this sense the pacemaker of the cycle (Schneirla, 1944*a*). This performance is formidable, involving as it does the delivery of a great series of eggs within a limited period of days about midway in each statary phase. In *E. hamatum* the queen lays more than 50,000 eggs at intervals of about 36–37 days, in *E. burchelli* she lays more than 120,000 eggs at intervals of 32–37 days. What timing mechanism controls this rhythm?

The hypothesis of a control strictly endogenous to the queen can be examined at present only by indirection. There is one striking indication that periodic ovulation in the Eciton queen is not a response to an internal "time clock." When a colony has its infrequent, usually annual sexual brood of males and fertile females, the interval between broods is shortened by nearly one week in both of the investigated species. This difference may be attributed to a more accelerated larval development of the sexual forms than with all-worker broods (Schneirla, 1948; Schneirla and Brown, 1952). But the queen's next egg brood is then delivered as usual, midway in the following statary phase, in time with the colony cycle although much earlier than a strictly endogenous control might have dictated. This suggests that the stimuli essential for oviposition are extrinsic to the queen, and come either from the physical environment or from within the colony situation.

Among conceivable extrinsic controls, none of the more obvious physical periodicities seems likely. First of all, neither of the two established Eciton species rhythms falls into step with the periods of any regular physical event such as lunar phases as Weber (1943) suggested. Also opposing a linkage controlled by such events is the fact that among a number of colonies operating in the same general area at any one time, no significant correlation of phases is found (Schneirla, 1949; Schneirla and Brown, 1950). The answer must lie somewhere within the functions of the *Eciton* colony itself.

Figure 4 shows an Eciton queen in the fully contracted condition, which prevails through most of the nomadic phase, and one in the physogastric condition with maximally enlarged gaster, normally invariable for these queens during the period midway in each statary phase. These conditions alternate regularly (Schneirla, 1944*a*), making it clear that a contracted queen is not necessarily a virgin or a young female, as was previously assumed (e.g., Wheeler, 1925; Borgmeier, 1933; Bruch, 1934). The time relations of the transition from one to the other of these conditions in the two species are indicated in figure 5, in terms of the gaster length of queens

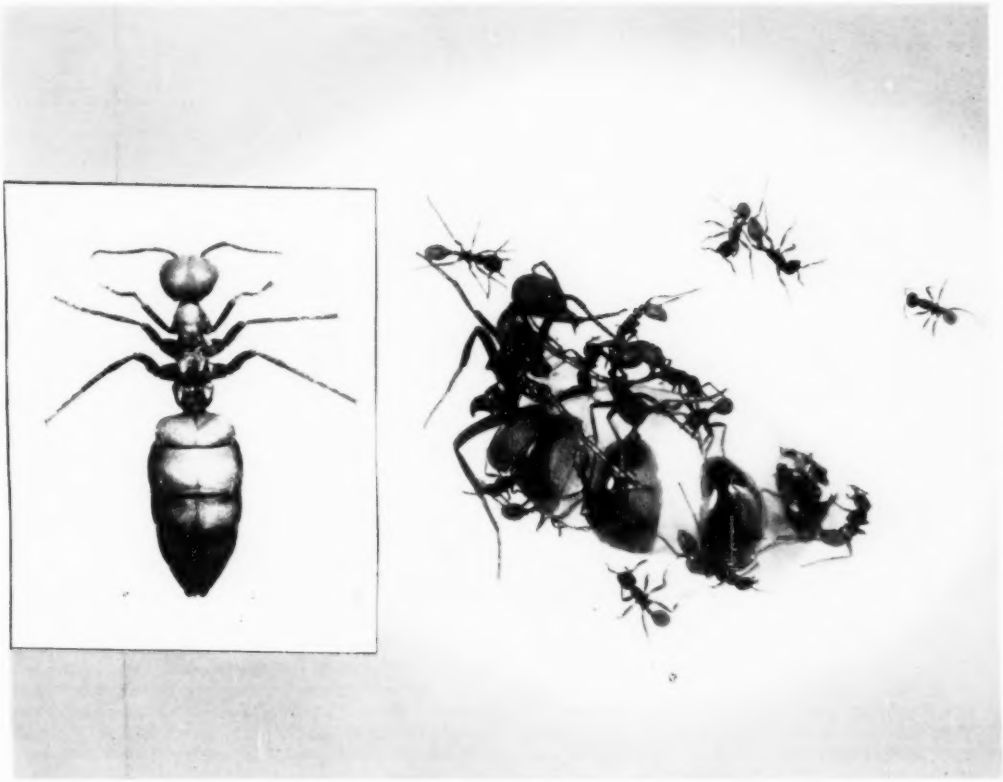

FIG. 4. Functional queens of *Eciton burchelli*, photographed in the laboratory after removal from their colonies. *Right:* a queen ('46 B–IV) captured on the tenth statary day of her colony, when she was *physogastric* and at the height of egg-laying. *Left:* a young colony queen ('52 B–I$_8$) with *contracted gaster* (gaster length, 10.4 mm.), taken from her colony near the end of the statary phase in which her first egg-laying had occurred. Her gaster, although still somewhat distended, is approaching the minimal size characteristic of the nomadic phase (*cf.* fig. 5-B).

measured at different stages in the functional cycle. It is clear that the condition of the functional queen in any epigaeic Eciton colony is *reversible* with respect to physogastry, and always predictable from colony behavior or from the condition of the developing broods present (*cf.* figs. 1 and 5).

Conditions initiating physogastry:

The histological studies of Hagan (1954) with queens of *Eciton hamatum* and *burchelli*, and others of the genus collected by me in Panama and in Mexico, show that the increase in gaster length toward the end of the nomadic phase as indicated in figure 5 parallels the only progress of the cycle into a condition of egg delivery (fig. 6). There is then a recrudescence of the fatty tissues of the abdomen, with an accelerated maturation of oöcytes to completion in the ovarioles. This condition advances to full physogastry and egg-laying, midway in each statary phase, a process which (from field observations) lasts about seven days in the queen of *E. hamatum* and about ten days in the queen of *E. burchelli*. But why does this change in the queen (marked by an increase in volume of the gaster) begin late in each nomadic phase, and not at some other time in the cycle?

The available facts indicate that the Eciton queen's periodic resurgence into physogastry is due to a change in her relationship to the colony, based upon conditions which can arise, normally, only once in each cycle. This is the time men-

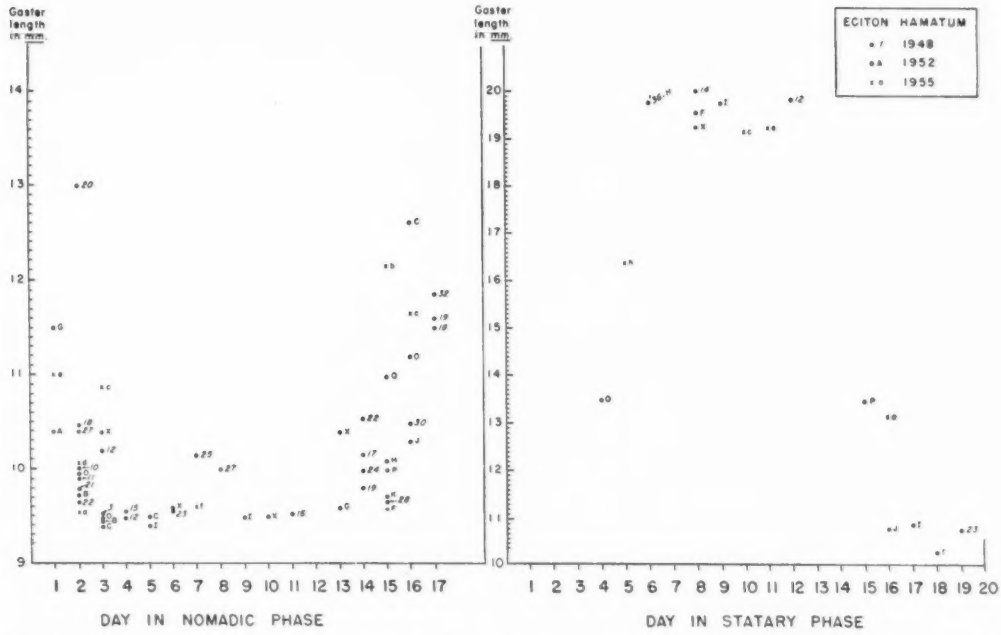

FIG. 5 (A). Gaster length in *mm.* of queens of *Eciton hamatum* measured at specific different times in the functional cycle. Symbols designate the queens of different colonies for convenience in comparing those measured more than once (e.g., queen *'52-X*, 3d and 10th nomadic days, 8th statary day). Queens *'48 H-20* (2nd nomadic day) and *H-25* (7th nomadic day) had somewhat flabby gasters and were judged to be elderly; queen *'48 H-27* (8th nomadic day) was a callow queen recently established in a daughter colony after a colony division, and hence subject to overfeeding (*see text*). Gaster lengths of 9.4, 10.0 and 10.2 *mm.* correspond to gaster widths of 5.0, 5.5, and 5.6 *mm.*, and to body weights of 0.122 g., 0.132 g., and 0.135 g., respectively.

tioned, when a larval brood nearing maturity excites the workers increasingly, but feeds decreasingly. Then, as raids increase in size, a food surplus arises and persists in the colony. The highly aroused workers busy themselves not only with the larval brood, but also increasingly with the queen. She receives mounting social stimulation through antennal stroking, licking, mouth contacts, and other grooming from workers, which must excite her to feed more and more voraciously on the food heaped around her in the bivouac. It is very probably the high pitch and persistence of stimulation from workers that primarily induces the voracious feeding, and not simply the abundance of food. Food surpluses may arise at other times in the nomadic phase, without bringing the queen to physogastry.

It appears, then, that approach to maturity in the larval brood brings with it behavioral and trophic conditions adequate to change the queen from a contracted condition into full reproductive function. The egg-laying condition evidently is set off by *extrinsic* factors, and no timing mechanism intrinsic to the queen need be postulated. When the necessary turn of events is reached in the functional cycle, the normal Eciton queen responds to her full reproductive capacity.

Therefore, the Eciton cycle may be considered a self-rearousing system, in which the reproductive unit is linked periodically into a critical participation. Actually, the function of the queen herself sets off processes which at a later stage, in a feed-back manner depending upon brood development, serve to arouse the specific timing mechanism for her next contribution to the repetitive cyclic pattern.

Exogenous and endogenous control of ovulation:

At other times in the cycle, the queen's reproductive processes are held to a low level, evidently

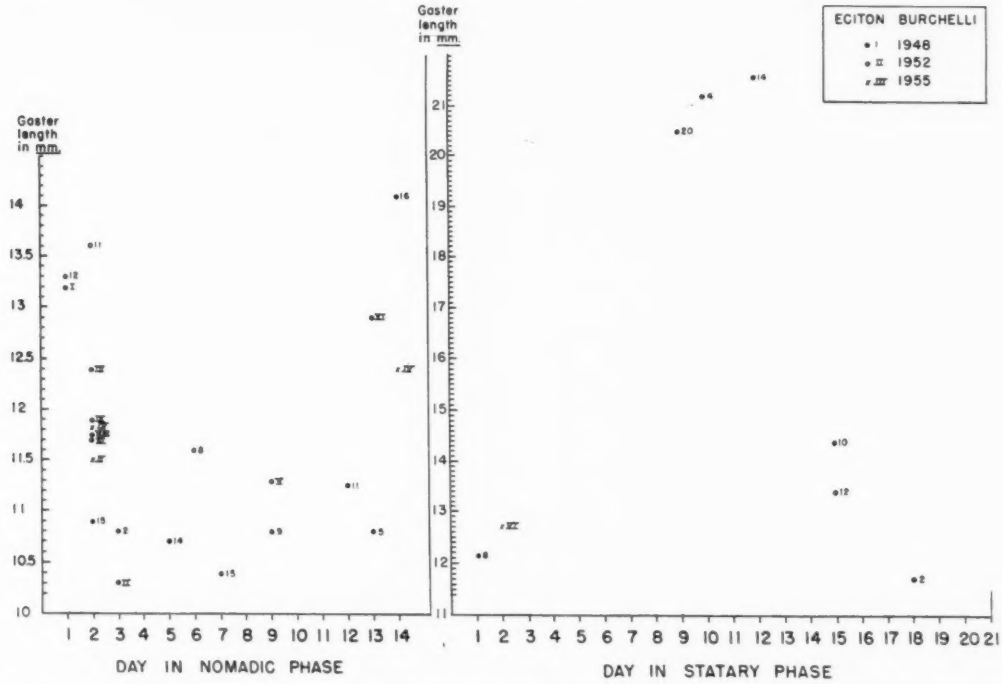

FIG. 5 (B). Gaster length in *mm.* of queens of *Eciton burchelli* measured at specific different times in the functional cycle. Queen *'48-8* (6th nomadic day) was suspected to be a callow recently established in a daughter colony after colony division, and hence subject to overfeeding. Gaster lengths of 10.2 and 10.5 *mm.* correspond to gaster widths of 5.2 and 5.5 *mm.*, and to body weights of 0.143 and 0.152 *g.*, respectively.

conditioned upon limited stimulative and trophic advantages. Points in the functional cycle at which significant rises occur in these conditions coincide with times at which Hagan finds appreciable advances in the development of overlapping generations of oöcytes within the queen. In the schema representing his results in figure 6, two significant changes are indicated for the time near the end of the statary phase at which a propitious trophic situation exists by virtue of conditions incident to pupal maturity. Here a maximal larval excitation of the colony promotes increased raiding, although meanwhile the brood consumes decreasing amounts of food. Significantly, Hagan's histological studies of the queen show that at this time (1) a new oöcyte generation makes its appearance, and (2) the previous oöcyte generation exhibits a limited developmental spurt.

But rigid limitations seem to hold for such advances in the ovulative processes of the queen. Thus when nomadism begins and the callow brood feeds voraciously, the queen promptly loses the condition of partial physogastry characteristic of this stage in the cycle. Figure 5 shows that her gaster length then falls to a minimum indicating full contraction before the third nomadic day. In figure 6 it may be seen that a leveling off then occurs in the development of the two current oöcyte generations from the limited accelerations just preceding.

The persistence of limited oöcyte development and a fully contracted gaster from this time nearly to the end of the nomadic phase would seem attributable to the presence of active brood. Voracious broods first of new callows, then of growing larvae, suggest a competitive situation maintaining low stimulative and trophic conditions for the queen, holding her at a low level of reduced metabolism with reproductive processes distinctly subdued. (In this condition, the role of inhibitory secretory factors may be suspected.) Hagan finds that the queen exhibits only a very slow and

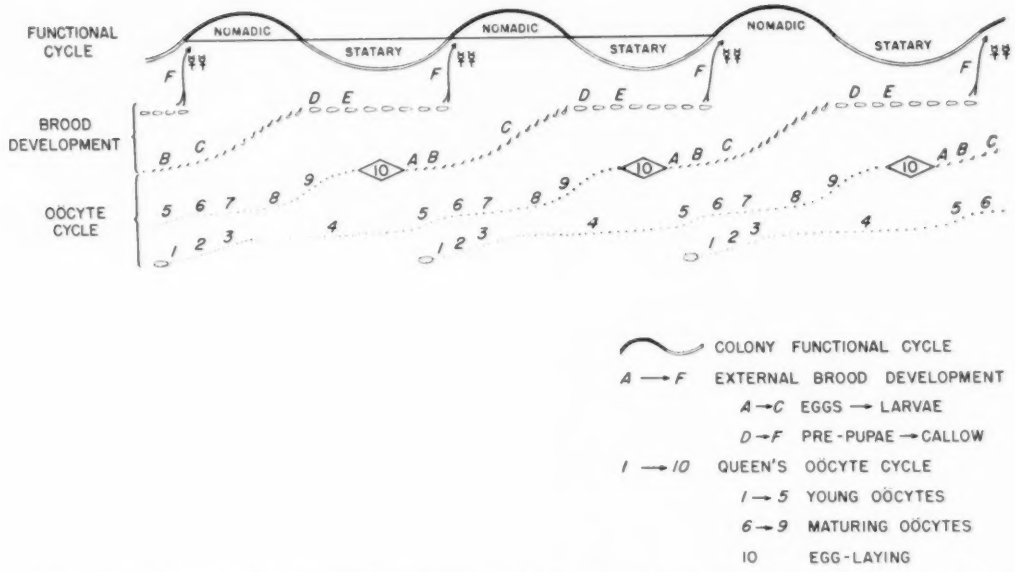

FIG. 6. Schema to represent corresponding conditions in the general Eciton colony situation as concerns the *functional cycle* (sine wave, *above*) and *external brood development* (*middle*, *cf.* fig. 1) from egg-laying (10-A) to emergence of the brood as callow workers (F-☿☿). Correspondence of developing generations in the queen's ovulation processes is indicated below (stages 1–10), based on the histological studies of Hagan (1954) on queens captured at specific different stages in the cycle. Correspondence of events at any stage is indicated in a vertical comparison.

limited advance in ovulative processes through the nomadic phase nearly to its end, when the next acceleration occurs as the larval brood nears maturity.

The case is different with the young queen of a new daughter colony, just after a colony division has taken place (Schneirla and Brown, 1950; Schneirla, 1956). Once established in the new colony, the primiparous queen is maintained in partial physogastry by means of a continuous overfeeding throughout the *entire* first nomadic phase following her eclosion. Oöcyte maturation evidently is brought thereby to a much more rapid completion than in adult functional queens. The young queen thereby reaches full physogastry and delivers a mass of eggs approaching normal brood size in the first statary phase after division—only about three weeks after her fertilization and less than thirty days after she emerged from her own cocoon.

Accordingly, we see that the *Eciton* queen's reproductive functions synchronize with the colony cycle from the beginning, although for the first broods somewhat differently from later. The Eciton pattern seems to involve a close control of the reproductive unit at all times, mainly through the effect of external processes in the colony functional situation. Whatever endogenous factors in the queen operate to curb the interim rate of ovulation [6] would seem to be maintained by minimal social stimulation and low feeding until the time when a sharp rise in these conditions operates to remove the block and admit the completion of an ovulation.

The initiation and termination of the alternating phases in the *Eciton* functional cycle seem to hinge upon major stimulative changes brought into play when a brood completes a principal stage in its development. That is, the duration of the nomadic phase depends upon a regular time relationship holding between eclosion of a mature pupal brood and attainment of larval maturity by the next brood. Similarly, the duration of a statary phase is precisely dependent upon the time required for an enclosed brood to attain pupal maturity. In these two *Eciton* species, as we have seen, durations of the two alternating func-

[6] As, for example, secretory factors; also, physical sequelae of the previous egg-laying, as Hagan's results suggest.

tional phases are highly predictable. It is evident that conditions affecting the rate of development in the massive discrete Eciton broods must be very regular and must have a high degree of stability characteristic of stages in the cycle.

Environmental Adjustments Critical for the Eciton Cycle

The bivouac and related processes:

With respect to the problem of the developmental milieu in these nomadic insects, too involved for a systematic treatment here, three main points may be considered. First is the fact that the temporary nest or bivouac of a colony also functions as the *incubator* of its broods. The successive bivouacs of a nomadic phase afford the developing larval brood a series of microclimatic situations all very similarly stable in their properties as concerns internal temperature conditions, and therefore humidity also (Schneirla *et al.*, 1954). Not only are the characteristic atmospheric variations of the tropical day leveled off so that a high regularity prevails in larval development, but conditions in the controlled microclimate facilitate a differential development through the brood population. One important outcome may be mentioned.

In an *E. hamatum* brood there is a time difference of about one week between the laying of the first and the last eggs of the series. At larval maturity this time difference, as measured by the onset of spinning in the largest and the smallest members of the brood, has narrowed to about three days. Quantitative studies of preserved broods (Lappano, 1955; Tafuri, 1956) have shown that the intermediate and minor members of a worker-brood series both in this species and in *E. burchelli* develop at correspondingly more rapid rates than do the potential workers major, maturing from the earliest-laid eggs (fig. 7). Significantly, our studies on the ecological properties of the bivouac (Schneirla *et al.*, 1954) show that the highest temperatures exist at bivouac center where the smallest brood members are located, lower temperatures at the margin where the largest are located—in fact, that the bivouac regularly presents an ecological gradient to the brood (Jackson, 1956). The regularity in diurnal bivouac conditions on which these facts depend is traceable particularly to behavioral reactions of the worker population normal to their daily functional routine and to the daily march of atmospherically induced responses (Schneirla *et al.*, 1954). Factors contributing to the regulation of bivouac properties must be considered vital for the adaptation of these Ecitons to a surface life.

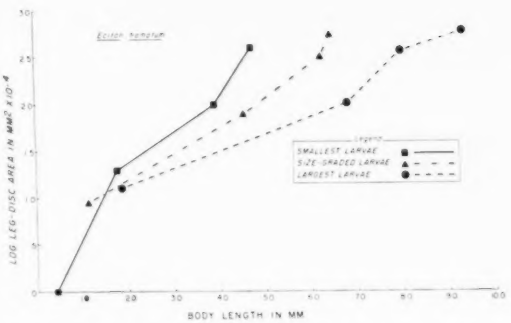

FIG. 7. Ratio of a local anatomical character (*log* leg-disc area, *ordinate*) to a measure of over-all size (body length, *abscissa*) in larvae from successive samples of an *Eciton hamatum* brood through the nomadic phase (from Lappano, 1955). From the origin, successive points on each curve represent averages for larvae in samples collected on the 2nd, 6th, 10th, and 14th nomadic days, respectively. ($N = 5$ in each measured lot of smallest and of largest larvae; $N = 20$ in each lot of size-graded or intermediate larvae.)

Adaptations concerning food supply:

Another principal environmental factor to which the *Eciton* cycle is adjusted is booty or food. Army-ant emigrations do not depend upon local food-scarcity as was formerly thought, as convincing evidence can be brought for a very different theory (Schneirla, 1938, 1944*b*, 1945). Even so, the fact is that mechanisms of the Eciton functional cycle normally furnish an adequate solution of the colony food problem. When active broods (callows, growing larvae) are present and the food-consuming capacity of the colony is highest, nomadism is maintained through the intense brood-stimulative processes outlined above. The colony thereby, *ipso facto*, is assured a fresh hunting area on each further day, different from that of the preceding day. Although worker reactions characteristic of the stage operate against entering previously worked areas, and favor new ground, the nightly emigration has causes only indirectly related to food-need or food-supply. With a comparable indirectness, when the food-consumption capacity of the colony is lowest in the statary phase, emigration does not occur; instead the col-

ony carries out successive daily raids from the same base but over radial trails established successively in different directions (Schneirla, 1945).

Through the Eciton cycle, a broad correspondence exists between magnitude of the colony food-consuming capacity on the one hand, and on the other the ability of the colony to gather food (through the size of daily raids) and the chances of finding more food (through emigration to new ground). This adaptive relationship is attributable to fluctuations in the level of brood-excitation effects, incidentally and indirectly controlling food supply. *The effect is independent of whether or not the brood, source of determinative stimulation, can feed at the time.* This fact is indicated by a higher level of daily raiding both in the initial and in the final days of a statary phase (table 4), owing specifically to a greater stimulative effect from *enclosed* brood than in the intermediate part of the phase. Besides, a new nomadic phase occasionally begins before more than a small part of the mature callow brood has emerged from cocoons and is feeding. This is seldom seen except with very large colonies, in which the communicative permutation of brood-excitatory effects evidently is greatest. Although Eciton workers are psychologically simple creatures incapable of a process of perceptual expectancy for an impending increase in colony food needs, the outcome of the described situation is highly adaptive—as effective as a housewife's buying more groceries for expected visitors.

Adaptations to the day-night rhythm:

A third environmental condition to which the epigaeic Ecitons are sensitively adapted is that of atmospheric factors such as light, temperature, and humidity. The characteristic Eciton daily routine of raiding followed (under appropriate conditions) by emigration is attuned directly to the day-night rhythm (Schneirla, 1938, 1940, 1944*b*). Werringloer's (1932) histological study of the eyes and their central connections in several species of American dorylines showed *E. burchelli*, the most epigaeic, to have the largest lateral ocelli and best developed neural connections; *Labidus coecus*, one of the most hypogaeic, tiny ocelli and minimal nerve connections. Adaptation to a surface life evidently has entailed a specialization of the visual system. This is only one factor, as a comparative consideration of hypogaeic dorylines shows.

Because the terrestrial Ecitons are photokinetically responsive to light in a highly sensitive manner, their activity routine involves the daily development of a raid, followed by an emigration or by none according to internal conditions in the colony. Consequently their activity phases are divided, as it were, into more or less equivalent units (e.g., in *E. hamatum*, 17 successive nomadic days), clocked by environmental conditions. The *Eciton* daily routine is mainly light-conditioned, with other physical factors involved secondarily. Increasing temperature facilitates the development of a raid each morning, high temperature with intense radiation inhibits raiding activities at midday—preparing the colony for a resurgence of activity with return of more equable outer conditions in early afternoon—falling temperature at dusk depresses activity as does failing light, stopping the raid and paving the way for a continued exodus or for return to the bivouac (Schneirla, 1938, 1940, 1945; Schneirla *et al.*, 1954).

The changing excitation level of an epigaeic Eciton colony during the functional cycle is clearly indicated by typical variations in responsiveness to environmental changes. In the nomadic phase, the workers are sensitively reactive to the first morning light, and raiding starts promptly at dawn. Although the midday depression involves a marked reduction of traffic on trails from the bivouac, traffic always continues, and the columns are promptly crowded again in early afternoon. Conditions are very different in the statary phase, and particularly in its intermediate days (*cf.* tables 2 and 4). Now the colony response is greatly reduced at dawn and exhibits a noticeable inertia; raiding builds up much more slowly or may fail altogether. The midday depression reduces raiding to a minimum, and in the dry season, when this effect is greatest, traffic often stops for some time for a considerable distance from the bivouac. Nomadic colonies in contrast are able to continue their raiding at such times.

In all three respects—the bivouac, adjustments concerning food supply, and reactions to light and other physical conditions on the surface—the epigaeic Ecitons exhibit adaptations essential to a regular life on and above the forest floor. These mechanisms and related types of behavior all contribute essentially to the maintenance of the highly specialized cyclic functional pattern characteristic of these species. It will be interesting to compare them in these respects with the more or less hypogaeic doryline species.

COMPARISON OF EPIGAEIC AND HYPOGAEIC DORYLINES

COLONY FUNCTION IN THE AFRICAN ANOMMA AND THE EPIGAEIC ECITONS

Recently, Raignier and Van Boven (1955) have reported that in the African driver ant subgenus, *Dorylus* (*Anomma*), the immense colonies interrupt long sedentary intervals with continuous emigrations each lasting 2–3 days. The colony movements, although somewhat variable in time of occurrence, come most frequently at intervals of about 20–25 days in the best studied species, *D* (*Anomma*) *wilverthi*. Significantly, these emigrations occur at times when a major part of the all-worker brood is in a mature pupal condition with individuals of the largest castes already ambulant as partially-pigmented callows. The colony then settles in a new subterranean nest from which it conducts successive raids through an interval of 20 to 25 days before a further emigration may occur. These authors also discern in *D.* (*A.*) *wilverthi* a less frequent inter-emigration interval of 11 days as well as one approximating 2 months when a developing male brood is present. In a less studied species, *D.* (*A*). *nigricans*, an inter-emigration interval of more than 100 days is reported, but in that case also the infrequent emigration is characterized by the presence of a majority of mature pupae in the brood (Cohic, 1948).

The situation reported for these African driver ants obviously bears some resemblance to the cyclic pattern in the epigaeic Ecitons of the New World. However, in *Anomma* the nomadic interval is very short and seems to involve just one bivouac-change movement of the colony, and also the interval spent in fixed nests is considerably more irregular in duration than in Eciton.

Raignier and Van Boven (1955: 241), as did Cohic (1948), find this state of affairs in the driver ants consistent in general with the terms of my theory for cyclic nomadic function in the Ecitons, in which nomadic function is attributed to causes dependent upon brood condition. Since, when emigration occurs in *Dorylus* colonies, mature nymphal forms always preponderate in the brood, it is stated that " . . . leur réserve énergétique et leur grande activité excitent la colonie au point qu'un déménagement s'ensuit." We may conclude that the principal if not the sole excitatory agency underlying emigrations in colonies of the investigated *Anomma* species is equivalent to that which I have described as the *callow-excitatory factor* (Schneirla, 1938) postulated as initiating a nomadic phase in colonies of epigaeic *Eciton* species. It is therefore not clear on what grounds the authors (*op. cit.*, 55) conclude that the causes setting an *Anomma* colony into movement are very different from those I have identified in *Eciton*. The main difference actually lies in what *follows* the emigration. Although the authors (*op. cit.*, 241) recognize that the basis of emigration in *Anomma* lies in reproductive processes, they offer only a very general suggestion as to how they think the adult population is aroused. As a more specific hypothesis, consistent with the modified trophallaxis concept I have found applicable to the Ecitons, the arousal may be attributed to the *summative effect of tactual and chemotactic stimuli from the brood*.

One striking difference between *Anomma* and *Eciton* is that, although nomadism in the former is confined to a single long colony movement, in the latter it involves a continuous phase at an increased level of activity with successive nightly emigrations. In both cases, we may say that the callow-excitation factor holds the colony in a highly aroused condition for about three days, then subsides as a major excitatory agent (*cf.* fig. 2). Raignier and Van Boven seem disinclined to adopt the concept of a functional cycle for the African dorylines studied. But even a single colony displacement lasting three days may be considered a *nomadic phase*, when based upon a brood-stimulated excitatory condition in the colony, and when it recurs at more or less regular intervals. Furthermore, the distinctive intervening periods in which the colony operates from a fixed site, with successive raids in different directions, clearly resemble *statary* intervals as I have described them for the epigaeic Ecitons (Schneirla, 1933, 1938, 1945). This latter condition holds until the maturation of a further nymphal brood occurs and the colony again emigrates. Contrary, then, to the conclusion of Raignier and Van Boven (1955: 241), the concept of a functional cycle involving alternating nomadic and statary phases seems applicable to *Anomma*, although in certain details the picture differs from that in the epigaeic Ecitons.

The major difference is that in *Anomma* the capacity for emigration disappears after one colony movement, whereas in the Ecitons it continues through a much longer phase. Theoretically, we may attribute the initiation of nomadism in both cases to the callow excitatory factor. But Raignier and Van Boven (*op. cit.*, 241), without a specific

citation, state for me that "Cet auteur trouve que chez les Doryles americains, le passage de la période sédentaire à la période nomade est occasionné par un appel croissant des larves à la nourriture." *On the contrary,* I have consistently held, that *newly eclosed callow brood* furnishes the stimulative effect initiating a nomadic phase (e.g., 1938: 64; 1952). To the stimulative effect of the *larval* brood I have attributed the *continuation* of nomadism in the epigaeic Ecitons, a factor viewed as thereby overlapping that of the callow brood in its arousal function. But also, diametrically opposing the sense of the above statement, I have postulated the larval factor also as one of *stimulative arousal,* and *not* "un appel à la nourriture." The latter expression would suggest the "Nahrungsbedürfnis" concept of Müller (1886), which I questioned as follows:

> Nahrungsbedürfnis suggests the point yet misses it. We are warranted in assuming only that the afferent consequences of larval growth processes result in random activities which incidentally exert a powerful excitatory effect upon the workers. . . . This indirectly forces the procuration of the larger quantities of food which the brood is then able to consume, since the adults raid more actively when more excited (1938: 69).

In any case, no larval-excitatory factor seems indicated in *Dorylus* as far as influencing the arousal of an emigration is concerned. Raignier and Van Boven always found larvae in the minority in the broods of emigrating colonies. But it seems possible that stimulative effects from developing larvae may account for a crescendo of raiding prior to emigration, and, somewhat as in *Eciton,* also (indirectly) promote ovulation in the queen.

It seems likely from Raignier and Van Boven's brood-samples that the *Anomma* queen may lay more or less continuously, but that a limited physogastry with a more intensive laying within 5–6 days may occur at intervals of about 3 weeks (*op. cit.,* 254), most frequently after arriving at a new nest.[7] But they find that in about one-third of the cases, the phase of intensive egg-laying begins a few days *before* the exodus. It is concluded that in one period of about 21 days, between emigrations, a quantity of eggs from some hundreds of thousands to as many as a million may be laid.

Egg-laying in Anomma queens is found (*op. cit.*) much more variable and more extended in time than I have found it in Eciton queens, in which it is restricted to an interval of about 7 days in *E. hamatum* and 10–12 days in *E. burchelli,* with a 2- to 3-day peak of delivery coming after the midpoint in each. Yet in Anomma queens there *is* a periodicity in the occurrence of high points in egg production, which Raignier and Van Boven attribute to an endogenous rhythm depending upon processes intrinsic to the queen. This conclusion may be premature. Further evidence concerning the effect on the Anomma queen of social stimulative processes and trophic conditions within the colony may indicate her egg-laying rhythmicity to be conditioned essentially by these, somewhat as I have found in *Eciton.*

The hypothesis of a brood-stimulative basis for such occurrences remains to be tested for *Anomma.* The statary phase indicated for *D.* (*A.*) *nigricans* (which is usually also the interbrood period in this species) is much longer than that typical for *D.* (*A.*) *wilverthi.* This wide difference would seem more likely to be based upon conditions holding for brood development than upon very different endogenously controlled ovulative rhythms in the queens of the two species. In view of the emphasis due the role of temperature in brood development (Schneirla *et al.,* 1954), it is significant that Raignier and Van Boven (1955: 192, 194) report a higher and more regular temperature ("physiologique") in the compact brood area of the subterranean nests of *wilverthi* than in the diffuse brood areas in the nests of *nigricans* colonies. Longer statary intervals and longer interbrood periods may be due simply to a much slower rate of development in the brood of the latter.

A PERSPECTIVE ON SOME HYPOGAEIC NEW WORLD DORYLINES

The hypogaeic nesting tendency, with or without surface foraging, evidently predominates in the remaining doryline genera of the world. Unfortunately, evidence concerning behavior and biological functions in these groups is at best sparse, and deficient on critical points. Something may be gained, however, by summarizing the fragmentary evidence for best-known species in genera other than *Eciton* in the tribe *Ecitonini.*

The epigaeic tendency, most predominant in the genus *Eciton* in species such as *burchelli* and

[7] This condition prevailed in a colony of *Dorylus* (*A.*) *nigricans arcens* in Ibadan, Nigeria, from which Dr. L. R. Aronson captured a physogastric queen, large quantities of eggs, and a great brood of mature pupae. The colony had just finished an emigration.

hamatum, is somewhat reduced in other species of the same genus such as *rogeri*. These, although at times found in surface bivouacs under humid conditions in deep forest, at times carrying out full column raids on the surface, are persistently subterranean in nesting and often make extensive use of underground avenues in their raids and emigrations. This capacity for intermittent surface operations, coupled with predominant subterranean nesting, also typifies species such as *E. vagans* and *E. dulcius*. Scattered evidence suggests that these species may approximate to differing degrees the functional and brood cycle of the epigaeic Ecitons. In humid forests with good cover, somewhat exposed bivouacs are found containing large larval worker broods, with the colonies raiding extensively, then emigrating; whereas other colonies are found in sheltered sites with enclosed pupal broods, settled and inactive, often then with signs that eggs have been laid (Schneirla, 1947).

Nomamyrmex crassicornis (= *E.* (*Lab.*) *crassicorne*) is persistently hypogaeic in its nesting, indicated by the fact that although its branching columns are frequently seen above ground in humid tropical American forests, the nest and queen are unreported. In humid forest, surface raiding operations occur often, exposed at times over areas up to 50 meters, but may disappear quickly underground. The emigrations, which may continue day and night for 30 hours or more, usually expose their columns on the surface for limited distances only, as in crossing streams. Each of three different emigrations of this species I was able to watch continuously for 12 hours or more contained many tens of thousands of callow workers. *Nom. hartigi* is reported as even more hypogaeic than *crassicornis* (Borgmeier, 1955).

Labidus praedator (= *E.* (*Lab.*) *praedator*) stages extensive swarm raids on the surface, more vigorously by day but also frequently at night. The species is strongly hypogaeic in its nesting, and colonies seem to occupy particular subterranean sites for long periods of time, often for months (Sumichrast, 1868; v. Ihering, 1912). Forel (1906) reported Fiebig's observation in Paraguay of an emigration column with workers carrying nymphs. On four occasions I have watched at length emigration columns of this species in which ran tens of thousands of callow workers, with great numbers of unopened small cocoons being carried along. The concurrence of emigration with the maturation of worker pupae in great numbers appears to be common in this species. Prior to such emigrations, the bivouac becomes partially exposed at the surface, e.g., permeating a log. Observations suggest that the queen may lay great quantities of eggs at these times. Luederwaldt (1918) observed a bivouac of *praedator*, in part exposed at the surface, in which he found numerous worker pupae and empty cocoons, and also eggs and microlarvae, with the queen physogastric. In a bivouac which I examined in detail in Eastern Chiapis in Mexico (Schneirla, 1947) countless chambers in a mouldy log were packed with a great enclosed brood of mature pupae, and in extensive chambers in the ground below were large quantities of eggs and microlarvae.[8] This pattern was substantially duplicated in two other observations, one of which was followed within 48 hours by an emigration. Statary nests occupied for intervals of six months or even longer have been reported for this species (Luederwaldt, 1918; Borgmeier, 1955).

Labidus coecus (= *E.* (*Lab.*) *coecum*), strongly hypogaeic, seldom is surface-exposed save for short stretches of column, even then usually largely beneath cover or roofed over with detritus particles. Raiding, elusive and mainly subterranean, seems to occur both night and day. To the statement of Wheeler and Long (1901) that *Lab. coecus* is "entirely subterranean," Creighton (1950) adds that, like many other army ants of strong hypogaeic tendency, this species will forage above ground "when the circumstances are suitable." This species evidently has *Dauercnester;* e.g., v. Ihering (1912) observed one colony continuously for more than four months, when it occupied an abandoned termite nest and chambers in the soil below. Weber (1941) found a colony occupying a rotted stump and the soil beneath, with "eggs and very young larvae," as well as whitish "cocoons of workers" containing pupae. The queen was distended with eggs. There is no evidence thus far to synchronize these events with emigration.

The genus *Neivamyrmex* (= *Acamatus*), which ranges from Iowa to Patagonia, has 113 currently described species (Borgmeier, 1955), in contrast to 12 in *Eciton*, 8 in *Labidus*, and 2 in *Nomamyrmex*. All are mainly hypogaeic. Although, of the described species, workers are

[8] This large colony was not raiding at the time, but was found quite by accident, after I had traced back the single foraging column of a colony of *E. vagans* to the same log, in which the two colonies were found in closely adjacent statary bivouacs.

known for 48 and all adults for 12, colony function and brood cycle are virtually unknown.

Neivamyrmex nigrescens (= *E.*(*Acam.*)*schmitti*):

In Texas, Wheeler (1900, 1910), in Argentina, Bruch (1934), and in northern Mexico, Creighton (1950) found colonies beneath stones at the surface, with partially physogastric, egg-laying queens present (*cf.* Holliday, 1906; Smith, 1942). Creighton (1950) suggests that a chambered nest of *Neiv. nigrescens* discovered by Wheeler and Long (1901) beneath a stone actually involved "a statary phase . . . " and that "the 'nest' was actually a permanent bivouac made during the period when the brood was about to pupate." Behavioral and biological conditions in Neivamyrmex colonies, and the conditions under which the nests are changed, are virtually unknown. Wheeler (1900) suggested for Texas species that the same nest is occupied during the winter and spring months, with departure to "resume their marauding expeditions . . . after the brood is raised in late spring." It is probable that brood production continues during the warm months.

Two suggestive cases concerning brood have come to my attention. In Georgia, Dr. E. S. Ross[9] found a colony nesting within and just below a log in the deep woods, with some thousands of mature pupae present, the largest castes pigmented; and Mr. Carl Rettenmeyer[9] found a colony near Lawrence, Kansas, from which a "small sample of mature larvae and a large sample of pupae nearing eclosion" were taken. A few days later, the colony was gone. The possibility exists that emigrations of Neivamyrmex colonies may occur in connection with the maturation of pupal broods.

DISCUSSION

The doryline ants throughout the tropics and subtropics of the world have retained primitive carnivorous dietary properties based on predatory foraging activities, and have developed reproductive capacities supporting large colonies, through an evolution evidently centered around nomadic patterns in colony function. This seems to hold throughout all doryline genera of the world, notwithstanding the probability that the Old and New World representatives have been isolated from the time of their theoretical common predoryline ancestor.

[9] Personal communication.

The outcome of evolution to date in this large formicine subfamily supports Wheeler's (1928) generalization that a predominantly carnivorous way of life cannot be maintained in a social insect with large colonies having permanent nesting sites. Dorylines universally seem able not only to shift their nesting sites and zones of foraging, but to do so in a more or less cyclical way. What all sections of the subfamily evidently have retained, and modified or specialized convergently, are mechanisms underlying predatory, nomadic species patterns closely related to large-scale reproductive processes through which such patterns are dynamized and sustained. An early stage in the evolution may have involved changes in colony nesting site enforced through depletion of food in the occupied zone. This is no longer true for any well-known doryline. Rather, the nomadic changes now seem due to stimulative colony arousal mechanisms based upon reproductive processes. But the prodigious reproductive capacities characteristic of the unique dichthadiigynes, or highly specialized queens functioning singly in doryline colonies, may have evolved in intimate relationship with selection processes effective through the trophic situation of their colonies. In the epigaeic Ecitons we find that this relationship still exists, although now in a specialized, self-rearousing pattern in which the critical reproductive factor is keyed off by stimuli released within the colony functional system itself. This formula may hold to some extent for all existing dorylines.

We are currently in a position to compare the functional pattern of certain doryline species in the Old and New Worlds, at least in a general way. It is unlikely that any doryline species departs from the pattern of a nomadic, predatory life based upon reproductive processes, established for *Eciton* and now indicated for *Anomma* as well. It seems likely that all doryline species will be found to possess a cyclicity in these functions, sustained through a recurrent system of excitatory relationships between colony behavioral processes and brood properties. This type of system, with massive brood-stimulative effects critical for major phases in colony behavior and their changes, prevails in the epigaeic Ecitons and is also indicated in the African driver ants.

The epigaeic *Eciton* species, best known at present, seem most highly specialized of all in their colony functional pattern. They are evidently more divergent in their specializations from the other, essentially hypogaeic dorylines of the Old

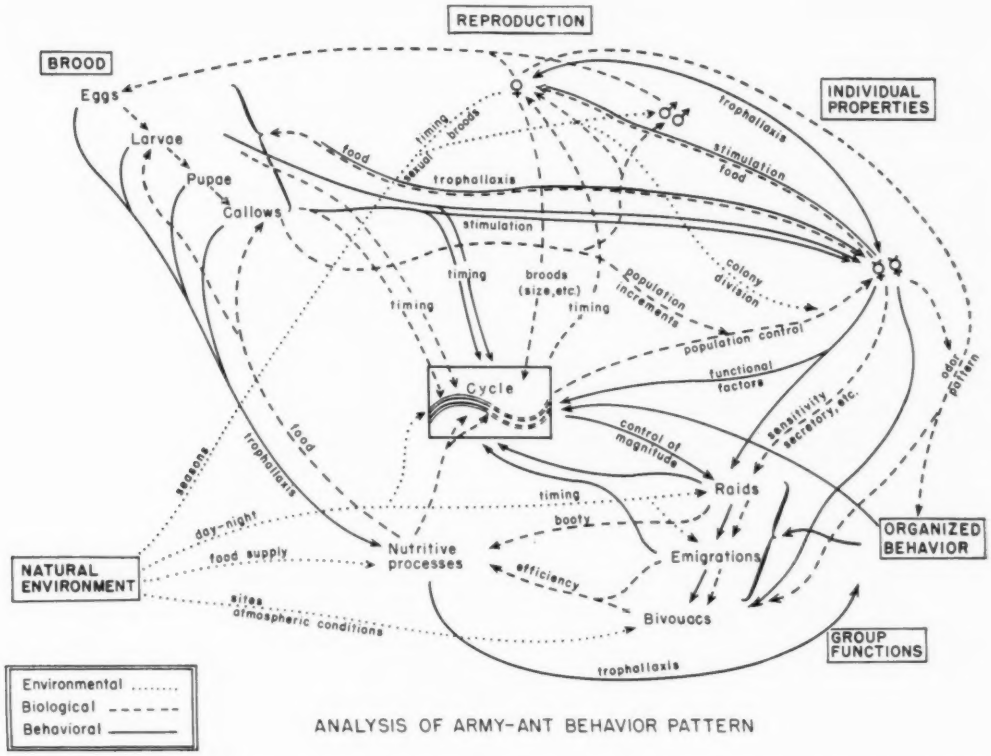

FIG. 8. Schema to represent the principal factors contributed by the natural environment and by major individual characteristics in the population to the epigaeic Eciton behavior pattern. The principal empirically established interrelationships of these factors are indicated by the respective connecting lines, the general adaptive relevance of each relationship is indicated by a label, and the main direction of the adaptive effect by an arrow direction. Differentiation of factors as "biological" or "behavioral" is a procedure of approximation. For example, food given by workers to queen and to brood has *both* a stimulative (behavioral) and a nutritive (biological) function, intimately related; the species odor-pattern has a variety of behavioral significances closely bound up with its biological properties, and so on.

and New Worlds than either of these is from the other. The inference seems justified that, whereas the Ecitons of the American tropics had a continuous environment of deep forest with heavy cover prevalent in which to pass the critical part of their evolution, the others including the African *Anomma* must have evolved under conditions of intermittent forest cover, of savannah conditions and the like. For the Ecitons, therefore, a selection process prevailed favoring the persistence and integration of factors consolidating colony adaptation to conditions on and above the forest floor. In contrast the other dorylines, evolving under conditions of broken or variable forest cover, were forced to subterranean adaptations in their nesting, all of them partly and some of them mainly if not entirely in their foraging as well.

The principal factors through which the specialized functional pattern of the epigaeic Ecitons has arisen are schematized in figure 8, with their chief interrelationships indicated. One factorial complex involves physical properties of the terrestrial environment such as the diurnal rhythms in light, temperature and humidity, or as the seasonal cycle. The characteristic Eciton routine of daytime raiding and nighttime emigration is clearly conditioned upon day-night physical variations, and first of all upon light. *Eciton* species such as *E. burchelli*, as Werringloer (1932) found, have much better developed lateral (pseudo) ocelli with much

better nervous connections than have members of the hypogaeic American doryline genera. Thus light has a distinctive photokinetic effect: the surface-dwelling colonies are aroused to build up their foraging systems in the daytime but are capable only of emigration and other more lethargic activities at night. Their visual equipment admits for them an effective light adaptation, and also, in their case, a heavier exoskeletal pigmentation opposes disruptive effects through intense light and surface radiation, permitting a scope of daytime surface operations far beyond that possible for species in other doryline genera.

The epigaeic specialization of the Ecitons clearly rests upon properties of the workers first of all. Sensitivity to light and to other physical radiation, as suggested, would seem critical for the consistently superior *Eciton* tolerance of surface conditions, and for relative differences among species in other genera in this respect. Werringloer's findings indicate a gradation in the photosensory factor among American dorylines from the most epigaeic species, *E. burchelli,* with best developed and best pigmented lateral ocelli, to *Labidus mars,* evidently most completely hypogaeic and the one American doryline species known to be *cyeless.* Comparative tests of mine on workers with experimentally covered eyes, as with *E. burchelli* and the very hypogaeic *Labidus coecus,* indicate that susceptibility to infra-cuticular radiative disturbance may be *least* in the epigaeic species and *greatest* in the most hypogaeic species. Other ecologically effective properties of the workers, as those affecting species temperature optima and relative desiccation tolerance, must also be ranked high in this respect. *Eciton rogeri* workers, although much more light-shy than *E. hamatum,* not uncommonly expose sections of their column raids on the surface; however, the rarity of even partially surface-exposed bivouacs in *rogeri* suggests a higher humidity optimum than in *hamatum.*

There is no reliable indication that worker properties affecting behavior in the raid (e.g., factors of sensitivity and of secretion underlying formation and use of trails; efficacy of mandibular bite and of sting, overall strength) are decisive for epigaeic or hypogaeic tendency. *Nomamyrmex crassicornis* resembles *E. hamatum* in the size range of its workers and in the branching-column aspect of its raids (often extended over considerable surface areas), yet the nests of the former are strictly hypogaeic and its emigrations are seldom seen. These species both take soft-bodied prey (e.g., insect brood) and are therefore competitive to an appreciable extent. *Neivamyrmex pilosus,* although in another genus and with much smaller workers, develops branched-column raids very similar to those of the above two species, but on a smaller scale, and captures soft-bodied booty, also relatively smaller. This species seems to be almost as fixedly hypogaeic in nesting and in basal raiding operations as *Nom. crassicornis.* As another comparison, *Eciton burchelli,* very epigaeic, and *Labidus praedator* (a hypogaeic nester as is *Neiv. pilosus*) have a similar swarm-raiding pattern (Schneirla, 1940) and capture a wide range of comparable booty, although in *Lab. praedator* both swarms and booty are smaller, roughly in relation to the smaller size of the workers.

Type of prey and type of raiding system appear not to distinguish the epigaeic species sharply from the hypogaeic, therefore, nor do virulence and persistence of attack. In both of these latter respects *Lab. praedator* and numerous other hypogaeic dorylines must be ranked before the epigaeic *E. hamatum.* Although the Ecitons tend to be larger in body size than the hypogaeic doryline species, there are exceptions (e.g., *Nom. crassicornis*), and the absence of a strict relationship suggests that the importance of this factor is secondary.

The extent of polymorphic differentiation among workers seems not closely related to relative epigaeic tendency, as in general the more markedly polymorphic *Labidus* species tend little more toward surface life than do the relatively more monomorphic species of the genus *Neivamyrmex.* However, from the fact that *Eciton* species all exhibit a wide polymorphic range extending to large workers major, the possibility cannot be excluded that some relationship may have existed between selective processes bearing on diversity in worker development and those contributing to an epigaeic way of life. Life on the surface involves not only ecological hazards, but also the danger of attacks against brood by a variety of predators including large mammals. Lacking the workers major, with their high arousal thresholds adapting them as defense units under conditions of extreme disturbance, and with their large, needle-sharp, tong-shaped mandibles as deterrents to the largest molesters, the epigaeic Ecitons probably could not have arisen in tropical forests containing mammals such as anteaters and coatis.

The formation of open, hanging bivouac clusters above ground is an exclusive property of the

Ecitons, when colonies are in the condition of increased excitement peculiar to the nomadic phase. Colonies of hypogaeic species in other genera (as in *Anomma*) also apparently have periodic times of increased excitement when in some species their nests are formed nearer to if not at the surface. Even then, however, the colony almost always remains partially rooted in the soil, and does not extend its nest above the surface except with the ecological protection of shelters such as the enclosing walls of hollow stump, log or debris. This resembles, without duplicating, the statary bivouac situation of *Eciton* colonies.

The open bivouac cluster is an inseparable characteristic of the Ecitons, in which they are exposed to surface conditions, and particularly to the light-dark rhythm upon which their daily routine of raiding and emigration depends. For this surface-adaptive accomplishment, characteristics of workers, brood, and queen all are essential (fig. 8). In all, exposure-tolerance properties are essential beyond those in the corresponding individual types of hypogaeic species. In the workers, better-developed tarsal hooks and effective clustering reactions are essential for the linking of bodies in large hanging masses. Here the larger workers, morphologically specialized, are indispensable, as is indicated by the larger cylindrical clusters and more frequent hanging bulb-clusters formed by the larger, stronger workers of *E. burchelli* than by those of *E. hamatum* (Schneirla *et al.*, 1954).

Nomadism in the dorylines seems dependent upon an interrelationship between characteristic worker properties and those of a specialized brood, accounting for relatively abrupt changes in trophallactic excitation conditioning critical variations in colony function. The massive arousal effect based upon maturation of a pupal brood seems to function similarly in all sufficiently known dorylines. This factor initiates nomadic phases in the Ecitons, and in the hypogaeic *Anomma* energizes single emigrations occuring at well-separated intervals. Scattered evidence for the hypogaeic American dorylines indicates that a pattern like that of *Anomma* may be approximated in their case. When better known, this may come to be regarded as the basic or "primitive" doryline pattern.

Thus far, the continuous nomadic phase of successive emigrations has been found only in the Ecitons, and may be a specific outcome of epigaeic specialization. In the Ecitons, a regular overlapping of synchronized broods involves the invariable presence of a larval brood in its early stages, when nomadism begins. A new factor enters thereby which can function as major colony energizer after the callow-stimulative effect has waned. Such a precise synchronization of broods would require, as control, either (1) a highly regular endogenous cyclic timing mechanism in the queen, (2) a precise external physical rhythm, or (3) a regular pattern of interrelationships among the functions of the main participants (worker population, broods, and the queen) in the colony routine. The last alternative is favored by available evidence.

The fact of regularity in brood development cannot be overestimated in its importance for the species-predictable *Eciton* cycle. The bivouac is an incubator for the brood, and an efficient one the properties of which seem due to a number of factors (Schneirla *et al.*, 1954). First of all, worker reactions to the odor field of the queen (posted in the upper center) seem essential to weld the cluster together, for a colony from which the queen has been taken soon forms less compact, increasingly diffuse bivouacs. This worker-queen relationship must contribute to centering of the brood in the cluster, a condition clearly essential to the thermo-regulation of brood development. The efficiency of the bivouac as brood incubator also may be related critically to a series of worker reactions to changing environmental conditions through the day, whereby for example the interior is ventilated in the heat of the day, and insulated from the outer atmosphere in a heat-conserving manner at night.

A routine of worker responses to the daily march of changes in the physical environment may be held vital for the emigration, which in these epigaeic species normally can occur only as a sequel to raiding (Schneirla, 1938). Dawn initiates the raid in a nomadic colony, midday environmental events contribute to further essential changes, and dusk makes the exodus dominant by closing off foraging activities. In outline, this is a threshold phenomenon. Through this regular process, new foraging ground inevitably becomes available on each further day in this phase, indirectly assured by active brood stimulatively energizing the adult population. The automatic nature of this brood-adult relationship, for which food transfer is incidental, is shown through the study of points in the cycle at which the excitatory process occurs at maximum although the brood then feeds only minimally if at all. Without these brood-adult relationships characteristic of the daily

routine, the Eciton brood-development schedule would be greatly disordered or at least more variable, disturbing the regularity of the nomad-statary cycle and as a consequence endangering colony existence.

The light-determined schedule of the daily Eciton routine, a worker-environment relationship, has the additional effect of assuring through a regular nightly emigration: (1) minimal interruption of raiding activities by bivouac-change traffic and (2) minimal exposure of the brood to environmental hazards. Vital to success in the regular epigaeic nomadism in colonies of Eciton magnitude is the fact that colony translocation in the early nighttime hours involves an exposure of broods (callows, larvae) *only* at the time of day when atmospheric conditions are fairly uniform on the forest floor and nearest the brood optimum.

Within the surface bivouac of the nomadic Eciton colony, conditions obtain which are vital in still other ways for the normal cyclic function of the colony. These adaptive results are gained through (1) trophic and environmental relationships of the colony which not only facilitate regularity in brood developmental processes but also (2) admit and control a species-predictable range of polymorphic differences in the brood. The first condition regulates the time required by the unitary brood to complete the larval and the pupal stages, thereby setting time limits for the nomadic and statary phases. More specifically, the properties of the bivouac as a specialized environment greatly increase the precision with which brood-stimulative factors initiate or terminate changes in the colony functional cycle. In Eciton bivouacs once settled after the emigration, the smallest members of the brood (developing from eggs laid last in the series) are always held in the center, the larger types more peripherally in relation to size. Thus the smallest members, virtually always in the zone of highest temperature (Schneirla *et al.*, 1954), can complete their development in a shorter time than respectively larger individuals (fig. 7). Consequently, the time-differential holding for the egg series is greatly reduced at later stages—e.g., in *E. hamatum*, from *ca.* 7 days at laying to *ca.* 3 days at larval maturity. The brood-stimulative effect thereby exerts a much more concentrated and a more intense impact upon the colony than if time relations at egg-laying held throughout. To this state of affairs we may attribute the fact that in the Ecitons the larval brood becomes a major factor influencing colony function, accounting for a striking time-limited change in colony behavior at its maturity.

In contrast, in the hypogaeic dorylines (as in *Anomma*), no larval-stimulative influence is as yet indicated in colony function, certainly none with the critical phase-timing role found in *Eciton*. It is likely that, for one thing, the time disparity in developmental rate in the brood series is too great to permit more than secondary influences on colony function until pupal maturity is attained. Numerous factors concerning queen, brood properties and colony ecological situation may be responsible for the difference. As concerns the brood factor, in the subterranean bivouacs of the driver ants, Raignier and Van Boven find that in the more concentrated clusters of *A. wilverthi* a "physiological temperature" prevails, evidently responsible for shorter brood-developmental intervals and shorter inter-emigration intervals than in *nigricans*, which lacks this ecological advantage.

The second condition mentioned above facilitates a greater polymorphic specialization in the graduated brood series than would otherwise be possible, so that worker types arise as different in their functional properties as the minima (essential in the centralizing and care of eggs and small larvae), the intermediates (essential for the brood gradient in bivouac; outstanding in raiding and in bivouac formation), and the workers major. The latter, as we have mentioned, are a unique defensive type critical for doryline adaptation to an epigaeic habitat.

Specialization of the doryline dichthadiigyne as a single colony reproductive capable of large-scale ovulative function presumably occurred intimately in relation to the evolution of brood-stimulative mechanisms underlying nomadism. In the Ecitons the queen must have undergone still further specialization with secondary advances of the social group to an effective epigaeic adaptation. One important specialization is the capacity for disjunctive broods separated by resting intervals. This property contributes to surface-adaptive advantages gained through more precise and more diversified brood-stimulative factors than are indicated in the case of hypogaeic dorylines. The Anomma queen, for example, seems to lay eggs over longer intervals or perhaps continuously, with periods of intensive production intervening. This condition, as compared with that of *Eciton*, may be considered basic to a lesser scope (i.e.,

reduction to a crucial pupal-arousal effect only) and greater time variability of brood stimulative effects as factors in the colony functional cycle. From Hagan's findings the Eciton queen is shown capable of initiating a new brood generation before the previous one has completed ovulation, a capacity fundamental to the adaptive asset of *overlapping broods* which makes possible a continuous nomadic phase. Through this property of the queen, the waning stimulative effect of a new callow brood is replaced smoothly in *Eciton* by the growing stimulative effect of a young larval brood, so that no break occurs in nomadic function until its completion at larval maturity.

On grounds already considered, I believe it is impossible to account for the reproductive periodicity of the Eciton queen either on the hypothesis of a strictly autonomous endogenous rhythm or as a response to an *extra*-colony physical rhythm. Rather, from evidence summarized in this paper, both the initiation of ovulation and certain well-marked intervening stages in the process, as well as the completed maturation and delivery of each specific brood generation as eggs, may be considered physiological responses of the queen to certain stimulative and trophic conditions in the colony adequate to instigate such changes. These we have described as feed-back relationships of the queen with the colony functional situation, through which she is *indirectly* responsible for the regular appearance of brood-excitatory factors critical for the colony functional cycle as well as for timing her own reproductive functions. All in all, however, the efficient operation of this complex timing mechanism depends upon a number of specialized functional interrelationships dependent upon the properties of workers, brood, and queen (fig. 8).

Raignier and Van Boven imply that the Anomma queen delivers her broods on the basis of an endogenous rhythm. Their evidence, however, seems inconclusive. In fact, their results as concern delivery of eggs and maturation of broods actually encourage a hypothesis of situation-stimulated queen function consistent with the theory offered above for *Eciton*. If we assume that new reproductive episodes in the queen are aroused through the effect upon her of trophic and stimulative changes in the colony, reported variations in the timing of egg-laying in queens of *A. wilverthi* become more understandable, as does the much longer interbrood interval suggested for the queen of *D. (A.) nigricans*.

Finally, one of the most striking aspects of Eciton epigaeic adaptation is a process of population control through which a complete colony emigration can be accomplished within a single night. Obviously, specializations in the queen are involved, since the Eciton queen lays considerably smaller broods than does the Anomma queen, for example. In contrast, hypogaeic tropical dorylines, characteristically with larger colonies than in *Eciton*, present a pattern of single emigrations with intervening stops over much longer intervals, relatively independent of the diurnal rhythm. In this process, brood-exposure in the daytime is reduced through worker behavioral mechanisms (as clustering and forming arcades of detritus) not observed in the Ecitons. Evidence considered earlier in this paper indicates that adaptive mechanisms influencing population control and the degree of hypogaeic life in general must involve not only the queen but all types of individual in the colony. If such mechanisms are to be considered ancestral or primitive on the grounds that hypogaeic patterns must be so classified, then it would seem that they have been lost or occluded in the course of epigaeic specialization.

CONCLUSIONS

1. In the ant subfamily *Dorylinae*, a predatory, carnivorous way of life has been widely combined selectively with large colonies, by virtue of a periodic nomadism in a cyclical pattern stabilized through a control by reproductive processes.

2. A nomad-statary pattern seems to hold in some form in all of this subfamily, with the essential energizing effect exerted by active stages of developing broods.

3. The Ecitons of tropical America, evolved under conditions of continuous deep forest and good cover, evidently have the most complex functional pattern of the group. Their essentially epigaeic adaptation is keyed to the diel light rhythm and the march of atmospheric changes as well as to other surface conditions. This pattern is centered around interrelationships among a complex set of factors arising through epigaeic adaptations in workers, queen, and brood.

4. The characteristic *Eciton* nomad-statary pattern is energized by two principal brood-stimulative factors: (1) a callow-excitatory factor initiating the nomadic phase, and (2) a synchronized larval-excitatory factor maintaining and at length closing this phase at a species-characteristic duration.

5. A general similarity is discernible between the functional pattern of the Ecitons and that of the African *Anomma* in the colony-energizing effect exerted by a brood at nymphal maturity, initiating nomadism.

6. Limitation of *Anomma* to a single continuous emigration of the colony in what may be regarded as a short nomadic phase is attributable to the absence of a larval-stimulative factor of sufficient strength to maintain the phase as in *Eciton*.

7. Adaptation in terms of a nomad-statary functional cycle may have evolved homologously in epigaeic and hypogaeic doryline species of both Old and New Worlds, with secondary differences as noted above.

8. With the Eciton queen perhaps the most specialized of all, the dichthadiigynes in the dorylines generally may approximate a periodic pattern in reproductive function. Queens of epigaeic and hypogaeic species may differ mainly in the precision with which successive ovulative episodes are delimited, and in the capacity for overlapping successive generations.

9. Cyclical variations in the reproductive functions of all doryline queens may depend, as in *Eciton*, not on an autonomous endogenous rhythm but on excitatory effects arising periodically through the trophic and social-stimulative situation of the colony.

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